

ACOUSTICS & ULTRASONICS



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Pen down

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

Inaudible

< 20 Hz

audible

20 Hz to 20,000 Hz

ultrasonic

Inaudible

>20,000 Hz

Audible Sound

Music – The sound which produces rhythmic sensation on the ears

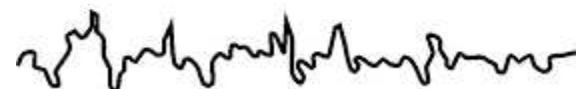
Noise-The sound which produces jarring & unpleasant effect

To differentiate sound & noise

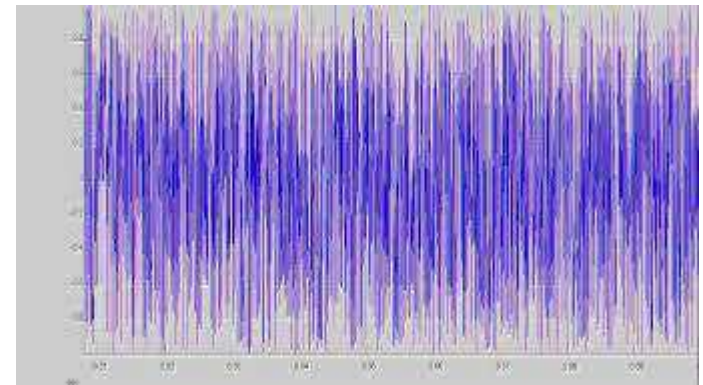
- ▶ **Regularity of vibration**
- ▶ **Degree of damping**
- ▶ **Ability of ear to recognize the components**



A MUSICAL NOTE

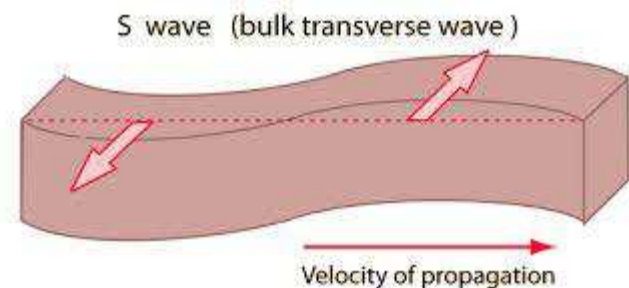
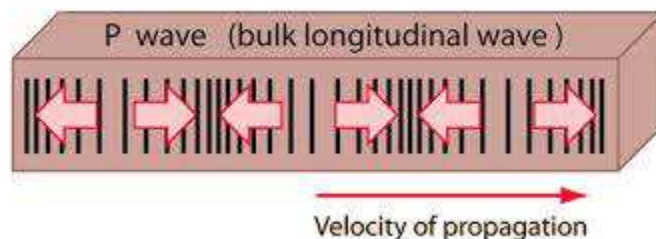


B NOISE



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. $c = 3 \times 10^8 \text{ m/s}$ $V_0 = 330 \text{ m/s}$ 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.

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

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

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.

$$L \propto \log I$$

$$L = k \log I$$

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

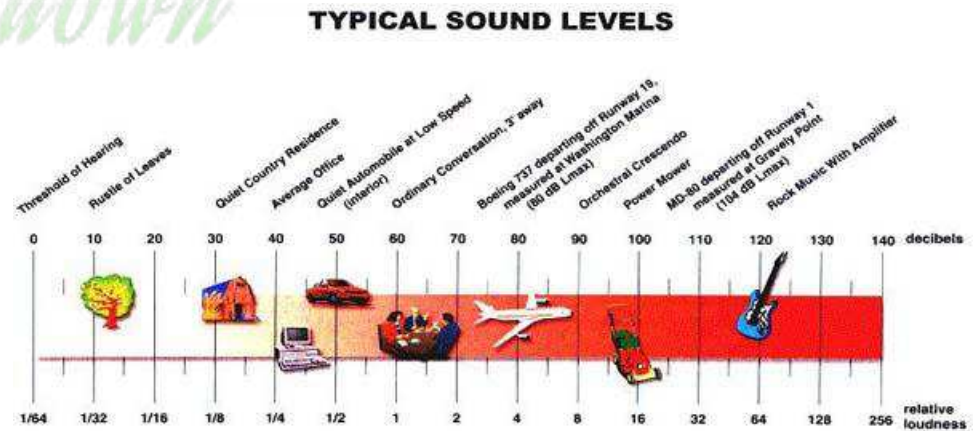
The maximum Intensity level

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

Phon

$$L_p = 10 \log I + 120$$

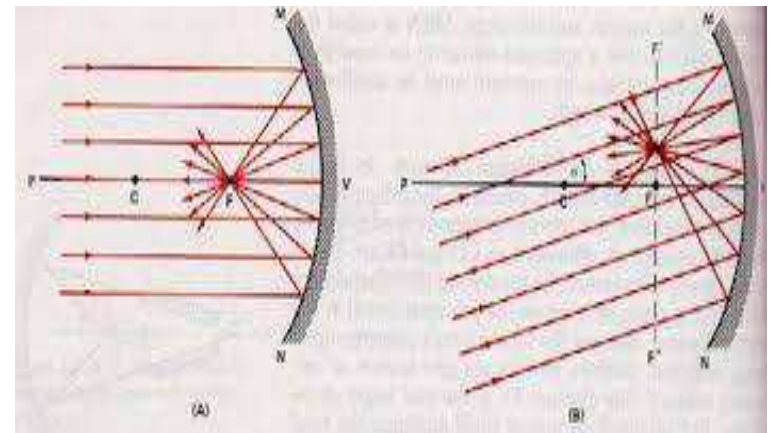
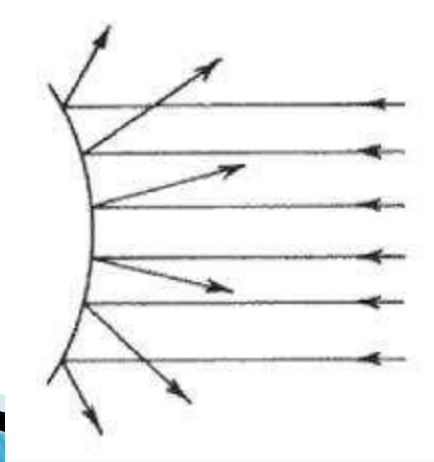
Here I = Intensity of sound in decibel



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.

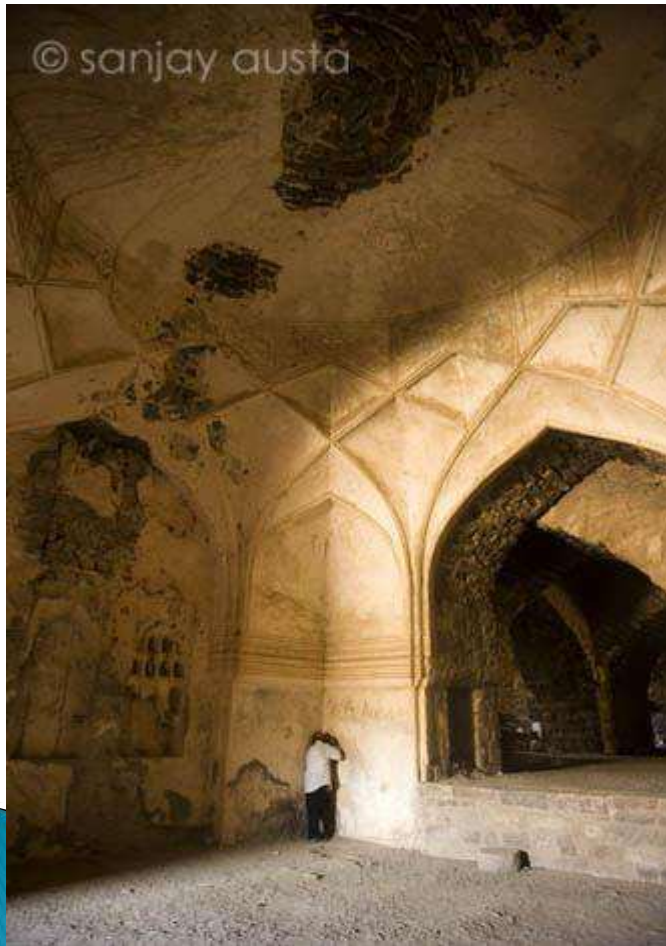
Acoustic Reflectors and absorbers

- ▶ Sound waves have freq 20 to 20,000 Hz means they have λ from $15 \mu\text{m}$ ($3 \times 10^8 / 20$) to $15,000 \text{ m}$ ($3 \times 10^8 / 20,000$).
- ▶ 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– Golconda Fort



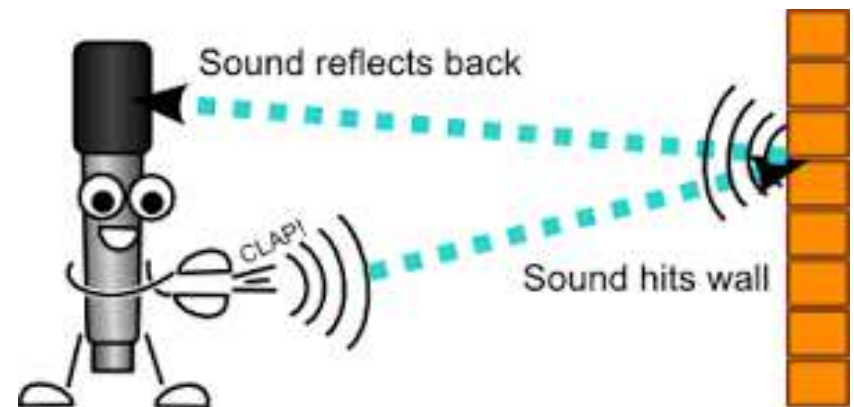
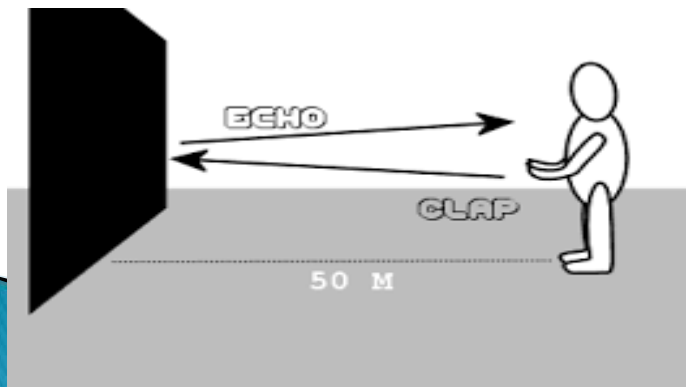
Reflection of sound causes two effects

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 $a = \frac{\text{sound energy absorbed by the surface}}{\text{total energy incident on the surface}}$
- ▶ 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

- ▶ $RT = \text{Volume of hall} / \text{Total absorption area}$

$$T = k V / A$$

$$T = 0.161 V / A$$

$$T = 0.161 V / (a_1 S_1 + a_2 S_2 + a_3 S_3 + \dots + a_n S_n)$$

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

$S_1, S_2, S_3 \dots$ = 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 m³, Theatre 4–5 m³, Public meeting 3.5– 4.5 m³)
- ▶ 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

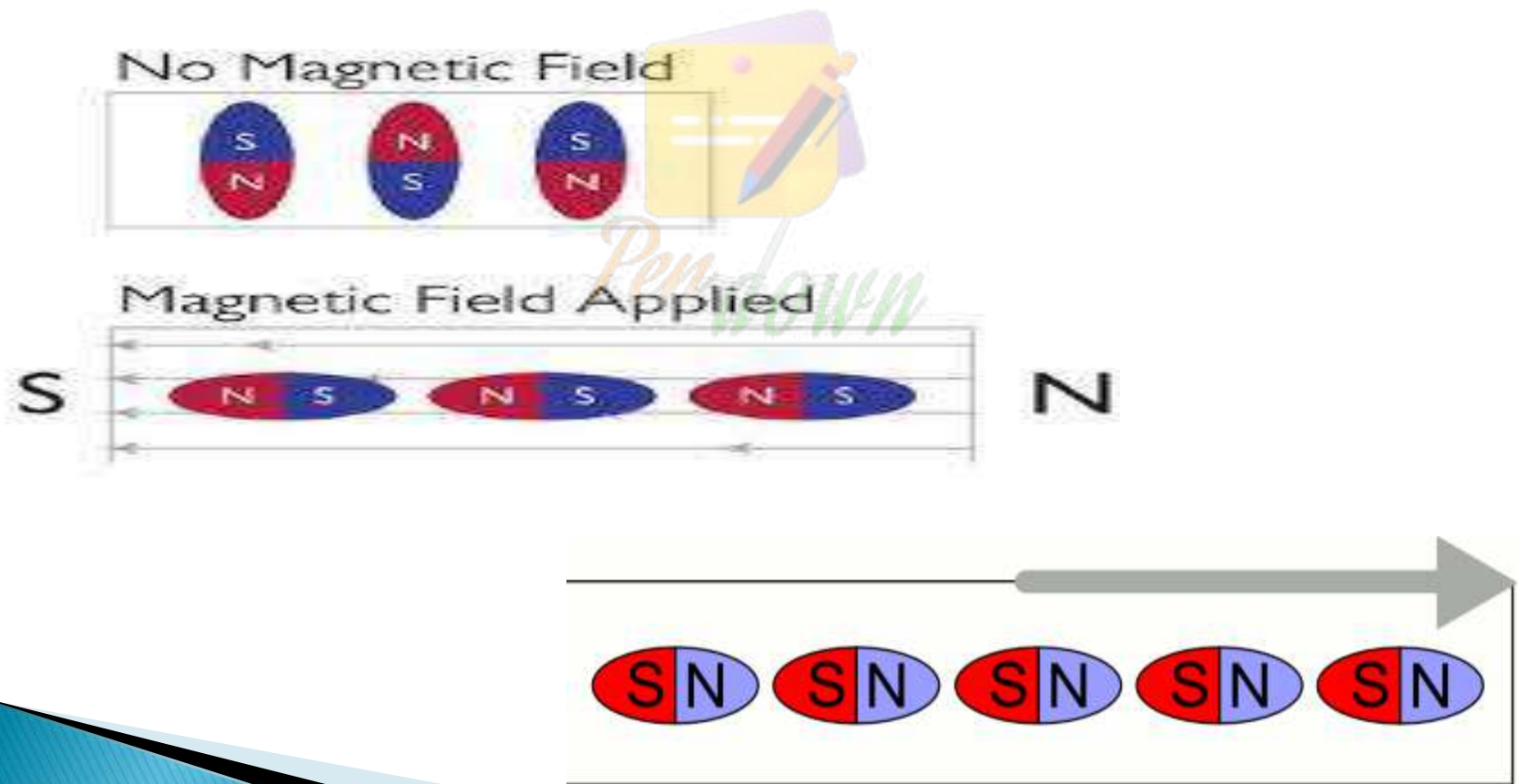
Ultrasonics deals with sound waves having frequency beyond audible range

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:

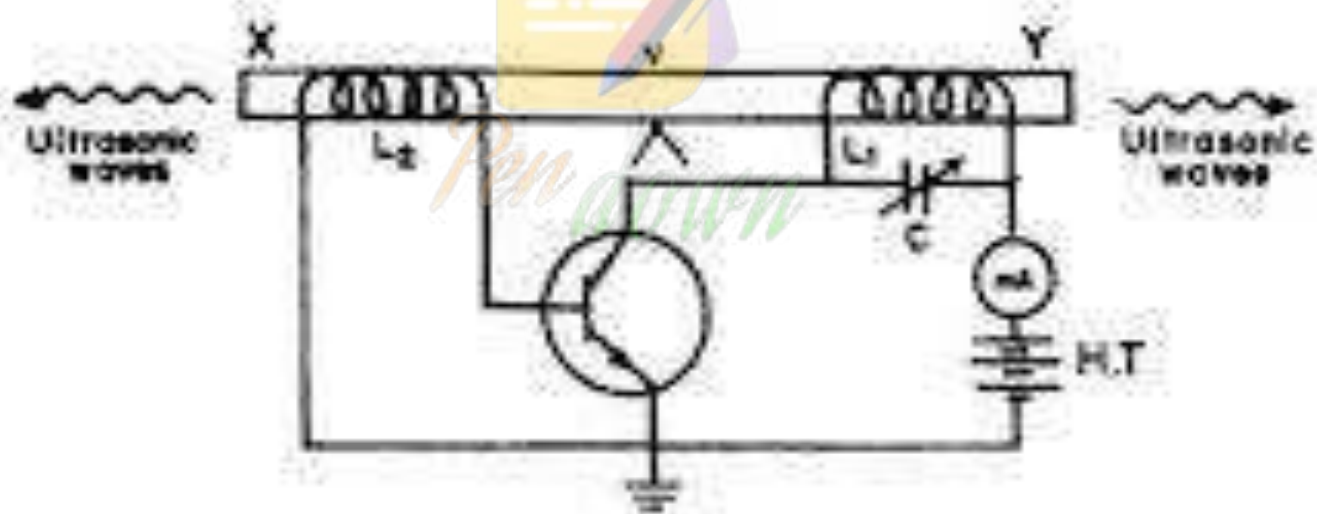
- ▶ Magnetostriction oscillator
- ▶ Principle: magnetostriction effect



Magnetostriction oscillator

Construction

The experimental arrangement is shown in Figure:

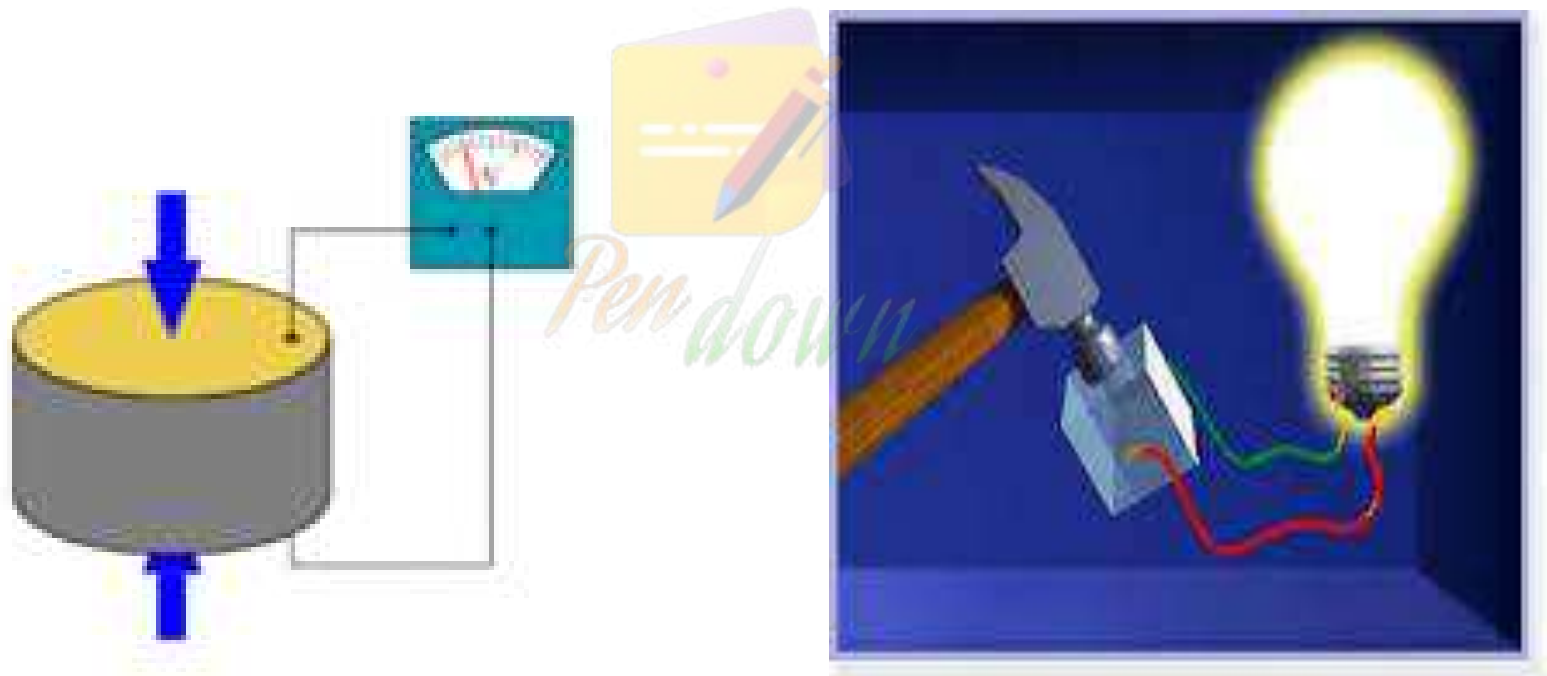


Magnetostriction oscillator

Piezo electric oscillator

Principle: Inverse piezo electric effect

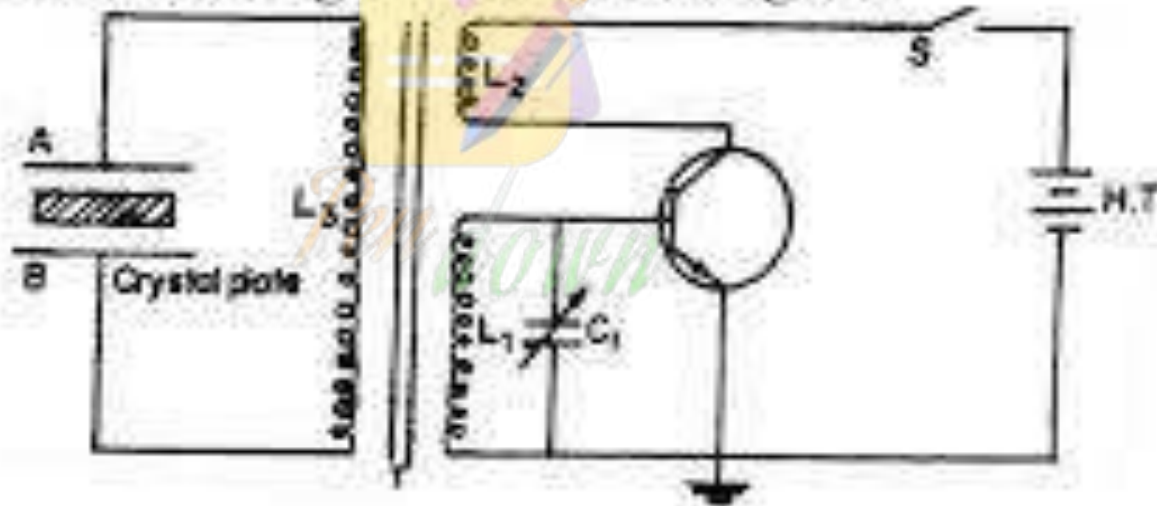
Diagrams: Piezo electric effect



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 & Garrifih's 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.

$$v = n\lambda$$

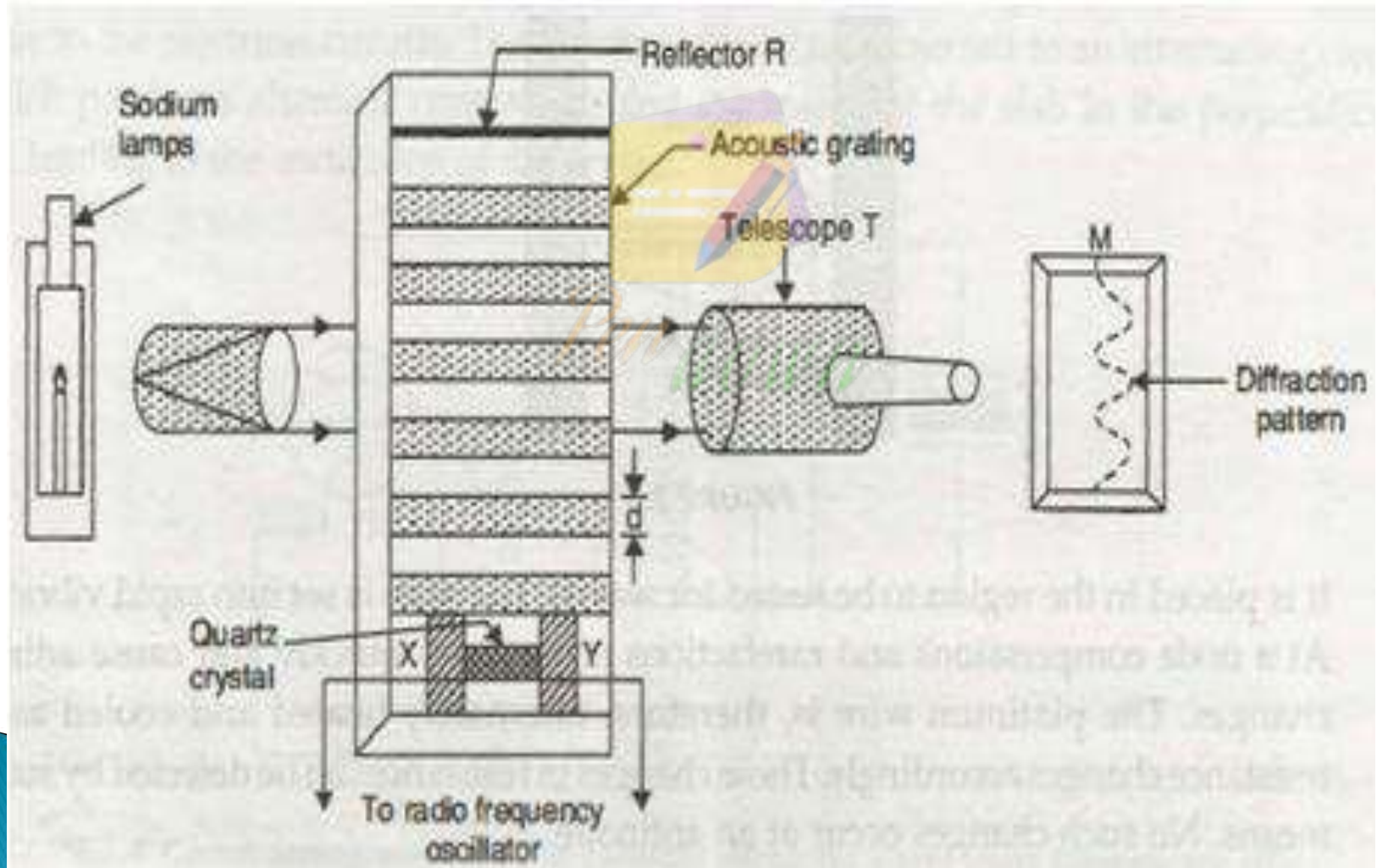
$$\lambda = 2d$$

$$v = 2Nd$$

N= resonant frequency of the piezo electric oscillator

d= distance between two adjacent nodes or anti nodes

Acoustic grating method – Detection of US waves

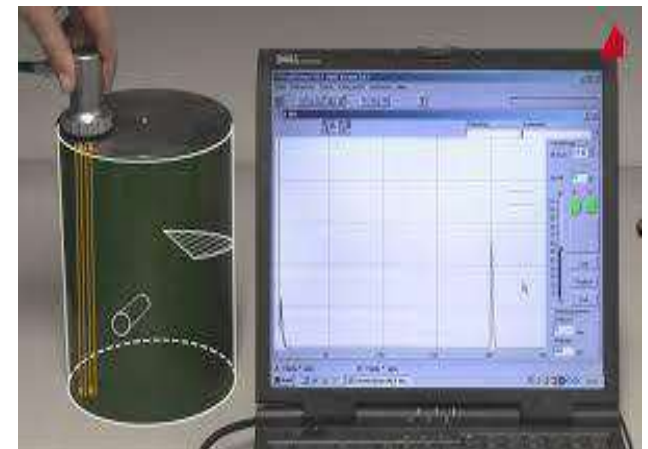
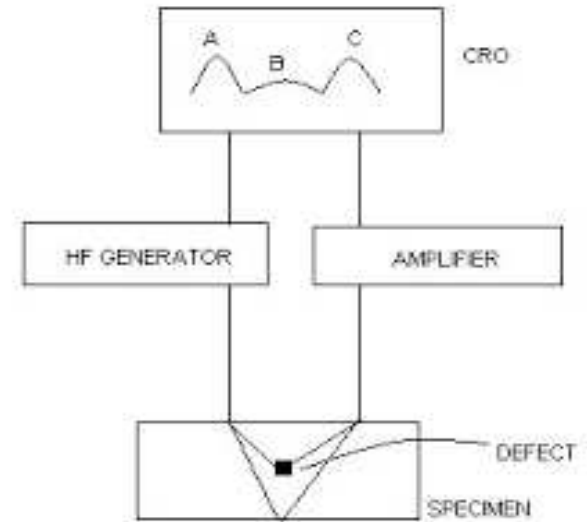
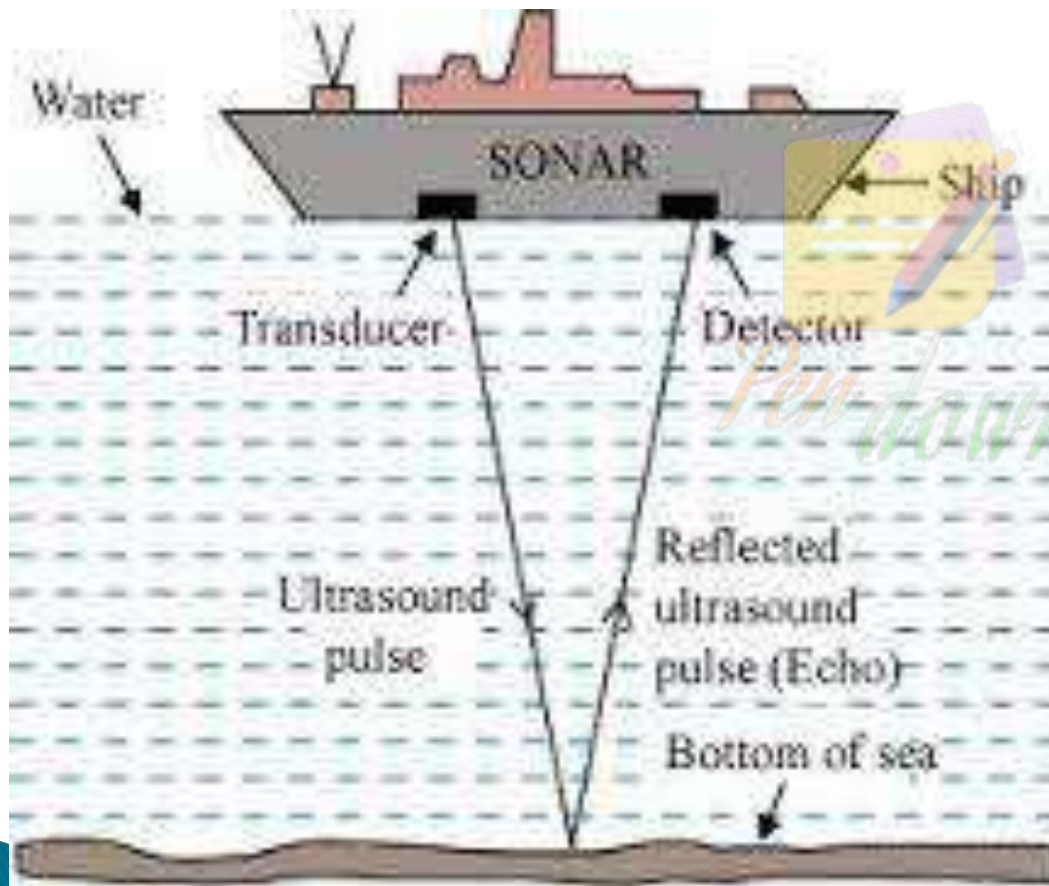


Applications of Ultrasonic waves

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

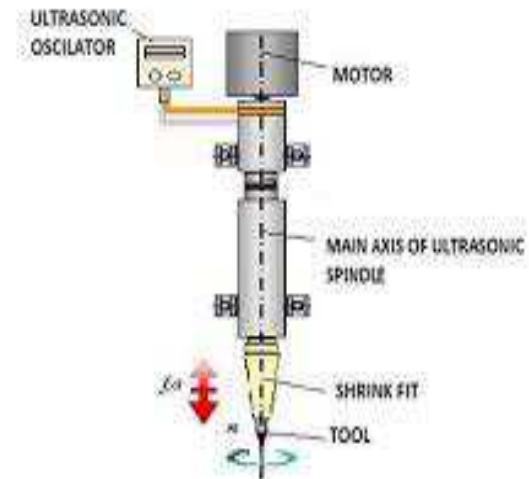
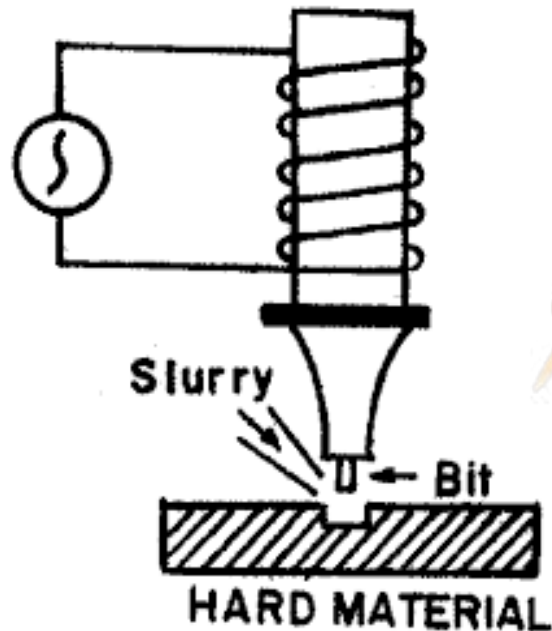


Applications of Ultrasonic waves– SONAR & NDT



US waves in the field of Industry:

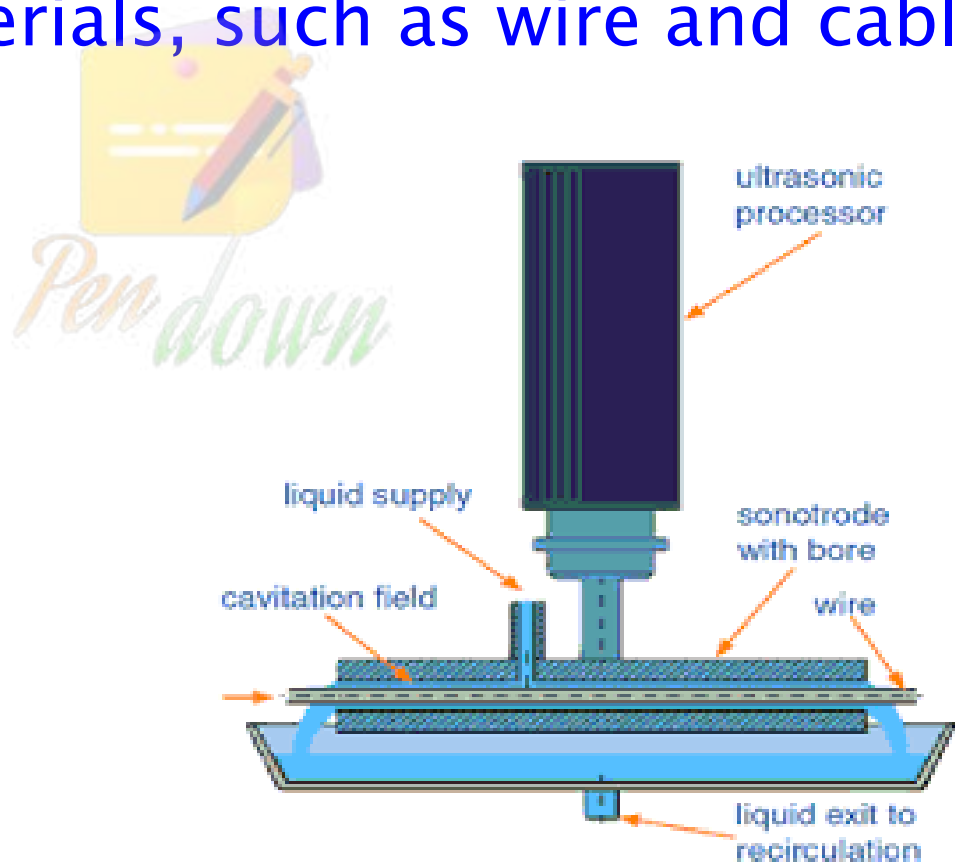
Cutting, drilling, welding, coining, grinding...



ULTRASONIC DRILLING PROCESS

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

