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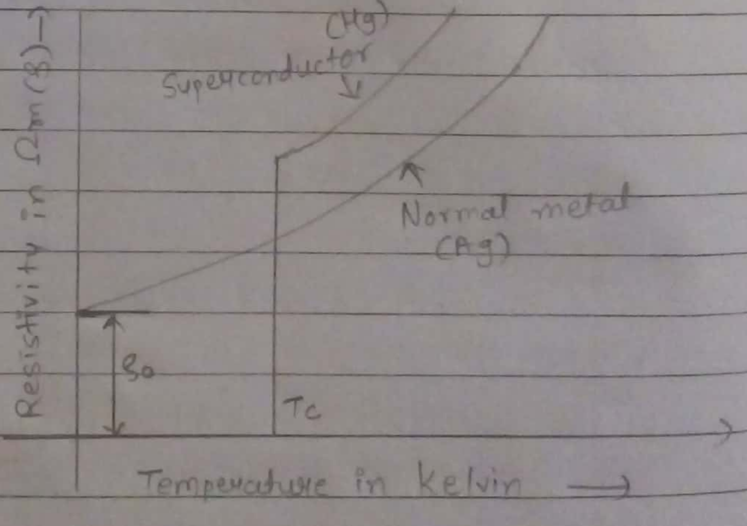
⊛ Superconductivity :-

⇒ Superconductivity is a phenomenon in which certain metals, alloys and ceramics conduct electricity without resistance when it is cooled below a certain temperature called the critical temperature.

⇒ A Superconductor is a material that loses all its resistance to the flow of electric current when it is cooled below a certain temperature called the critical temperature or transition temperature T_c.
Mercury (Hg), Zinc (Zn), Vanadium (V), Tin (Sn) and Niobium (Nb).

⇒ At the below T_c, the material is said to be in the superconducting state and above this temperature, the material is said to be in the normal state.



⇒ fig. shows the variation of electrical resistivity of a normal metal silver (Ag) and a superconducting metal mercury (Hg) versus temperature.

→ electrical resistivity of normal metal decrease steadily as the temperature is decreased and reaches a low value at 0K called the residual resistivity (ρ_0).

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But in contrast, the electrical resistivity of mercury suddenly drops to zero at critical temperature T_c. and is 4.2 K for Hg.

Below the critical temperature, not only does the superconductor suddenly achieves zero resistance it also exhibits a variety of several astonishing magnetic and electrical properties.

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⇒ Properties of superconductors

⊛ Electrical resistance

The electrical resistance of a superconducting material is very low and is of the order of 10^{-7} Ωm.

⊛ Effect of impurities.

When impurities are added to superconducting elements, the superconducting property is not lost, but the Tc value is lowered.

⊛ Effect of pressure and stress.

Certain materials are found to exhibit the superconductivity phenomena at Tc = 1.5K on applying a pressure of 110 Kbar.

In superconductors, the increase in stress results in increase of the Tc value.

⊛ Isotope effects.

The critical or transition temperature Tc value of a superconductor is found to vary with its isotopic mass. The variation in Tc with its isotopic mass is called the isotopic effect.

The relation between Tc and the isotopic mass is given by

$$T_c \propto \frac{1}{\sqrt{M}}$$ where M is the isotopic mass.

i.e., the transition temperature is inversely proportional to the square root of the isotopic moss of n single superconductor.

(4) Magnetic field effect

If a sufficiently strong magnetic field is applied to a superconductor at any temperature below its critical temperature T_c, the superconductor is found to undergo a transition from the superconducting state to the normal state.

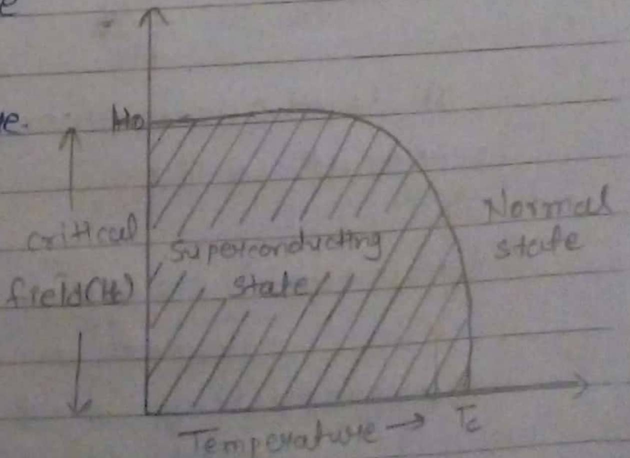
This minimum magnetic field required to destroy the superconducting state is called the critical magnetic field H_c.

the critical magnetic field of a superconductor is a function of temperature. The variation of H_c with temperature is given by

$$H_c = H_0 \left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

H_0 is the critical field at $T = 0K$. The critical field decrease with increasing temperature and becoming zero at $T = T_c$.

As shown the Fig. the variation of critical field H_c as a function of temperature. The material is said to be in the superconducting state within the curve and is non-superconducting in the region outside the curve.



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(5) Critical current density Jc and critical current Ic.

→ The critical current density is another important characteristic feature of the superconducting state.

When the current density through a superconducting sample exceeds a critical value Jc, the superconducting state is found to disapper in the sample.

Hence, the critical current density can be defined as the maximum current that can be permitted in a superconducting material without destroying its superconductivity state. The critical current density is a function of temperature, i.e., colder the temperature for a superconductor the more is the current it can carry.

For a thin long cylindrical superconducting wire of radius r, the relation between critical current Ic and critical magnetic field Hc is given by

$$I_c = 2\pi r H_c$$

Similarly, the relation between critical current density Jc and critical current Ic is given by

$$J_c = \frac{I_c}{A}$$

A is the superconducting specimen's cross-sectional area.

(6) Persistent current :-

When current is made to flow through a superconducting ring, which is at a temperature either equal to its Tc value or less than its Tc value, it was observed that the current was flowing through the material without any significant loss in its value.

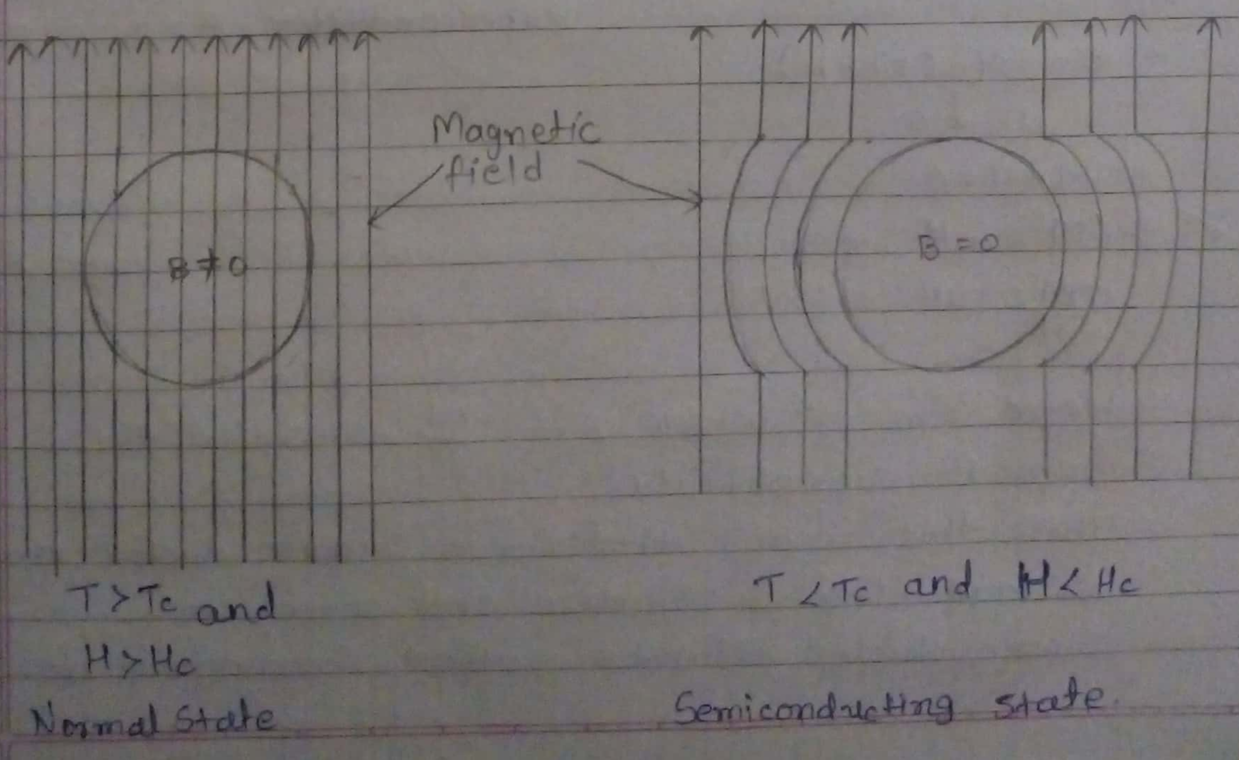
This steady flow of current in a superconducting ring without any potential deriving it is called the persistent current.

Meissner effect (Diamagnetic property)

the complete expulsion of all the magnetic field by a superconducting material is called the "Meissner effect".

When a superconducting material is placed in a magnetic field ($H > H_c$) at room temperature, the magnetic field is found to penetrate normally throughout the material

However, if the temperature is lowered below T_c and with $H < H_c$ the material is found to reject all the magnetic field penetrating through it, as shown in fig.



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The above process occurs due to the development of surface current, which in turn results in the development of magnetization M within the superconducting material. Hence, as the developed magnitation and the applied field are equal in magnitude but opposite in direction, they cancel each other everywhere inside the material. Thus, below Tc a superconductor is a perfectly diamagnetic substance ($\chi_m = -1$)

2) To prove $\chi_m = -1$ for superconductors.

We know that for a magnetic material the magnetic induction or magnetic flux density B is given by

$B = \mu_0 (M + H)$

μ_0 is the permeability of free space

M = intensity of magnetisation

H = applied magnetic field

superconductor B = 0

$\therefore 0 = \mu_0 (M + H)$

$\mu_0 \neq 0$

$M + H = 0$

$M = -H$

$\frac{M}{H} = -1$

Hence, $\chi_m = -1$ where $\chi_m = \frac{M}{H}$ is called the magnetic susceptibility.

Thus this means that for a superconductor the susceptibility is negative and maximum, i.e., superconductor exhibits perfect diamagnetism.

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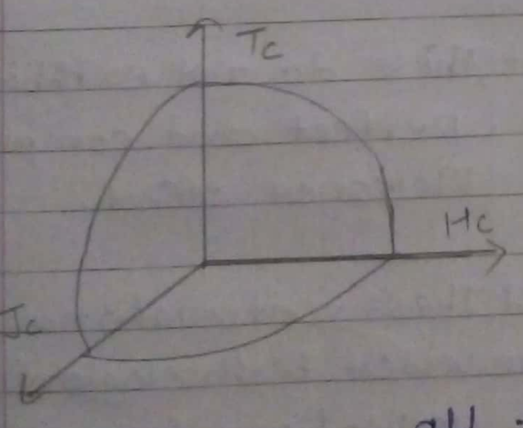
* Three Important Factors to Define a superconducting State :-

In general, the superconducting state is defined by three important factors:

i) Critical temperature T_c
ii) Critical current density J_c
iii) Critical magnetic field H_c

Each of the above three parameters is very dependent on the other two properties. To sustain superconducting state in a material, it is required to have both the current density and magnetic field, as well as the temperature, to remain below their critical values, and all of these would depend on the material.

The relation between T_c, J_c and H_c is shown in the phase diagram



The highest values for H_c and J_c occur at 0 K, while the Highest value for T_c occurs when H and J are zero. Thus, the plot of all these three parameters represent a critical surface.

Within the surface the material is superconducting and outside the surface the material is said to be in the normal state.

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⊛ Types of semiconductors.

Type I semiconductor	Type II semiconductor
⇒ These semiconductor are called as soft superconductor	These superconductors are called as hard super-conductor.
⇒ Only one critical field exists for these superconductors.	Two critical fields H_{c1} (lower critical field) and H_{c2} (upper critical field) exists for these superconductors.
⇒ The critical field value is very low.	The critical field value is very high.
⇒ These superconductors exhibit perfect and complete Meissner effect.	These do not exhibit a perfect and complete Meissner effect.
⇒ These materials have limited technical applications because of very low field strength value. Ex:- Pb, Hg, Zn, etc.	These materials have wider technological applications because of very high field strength value Ex:- Nb_3Ge, Nb_3Si, $Y_1Ba_2Cu_3O_7$, etc.

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(4) The critical field for Vanadium is $10^5\ Am^{-1}$ at 8.58 K and $2\times10^5\ Am^{-1}$ at 0 K. Determine the T_c value.

→ $H_c = 10^5\ Am^{-1}$,
$H_0 = 2\times10^5\ Am^{-1}$
$T = 8.58\ K$
$T_c = ?$

$$H_c = H_0\left[1-\left(\frac{T}{T_c}\right)^2\right]$$

$$\therefore \left(\frac{H_c}{H_0}\right) = 1-\left(\frac{T}{T_c}\right)^2$$

$$\therefore \left(\frac{T}{T_c}\right)^2 = 1-\left(\frac{H_c}{H_0}\right)$$

$$\therefore T_c = \frac{T}{\sqrt{1-\left(\frac{H_c}{H_0}\right)}} = \frac{8.58}{\sqrt{1-\frac{10^5}{2\times10^5}}} = \frac{8.58}{\sqrt{1-0.5}}$$

$$= \frac{8.58}{\sqrt{0.5}} = \frac{8.58}{0.7071}$$

$$T_c = 12.1334\ K$$

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⊛ The critical temperature for a metal with isotopic mass 199.5 is 4.185K. Calculate the isotopic mass if the critical temperature falls to 4.133K.

⇒ $M_1 = 199.5$;

$T_{c1} = 4.185\,K$;

$T_{c2} = 4.133\,K$;

$M_2 = ?$

$M_1^{\alpha} T_{c1} = M_2^{\alpha} T_{c2}$

$M_2^{\alpha} = (199.5)^{\alpha} \dfrac{4.185}{4.133}$

$M_2^{0.5} = (199.5)^{0.5} \times 1.01258$ $\left[\because \alpha = \frac{1}{2}\right]$

$\sqrt{M_2} = \sqrt{199.5} \times 1.01258$

$= 14.124 \times 1.01258$

$M_2 = 204.55$

⊛ Calculate the critical current through a long thin superconducting wire of radius 0.5nm. The critical magnetic field is 7.2 kA/m.

⇒ $H_c = 7.2 \times 10^3\,A/m$, $r = 0.5 \times 10^{-3}\,m$, $I_c = ?$

$I_c = 2\pi r H_c$

$= 2 \times 3.14 \times 0.5 \times 10^{-3} \times 7.2 \times 10^{3}$

$I = 22.608\,A$

Magnetic Leviation (Maglev)

⇒ Magnetic leviation or maglev is the process by which an object is suspended above another object with no other support but magnetic field.

⇒ A diamagnetic substance repels a magnetic field. Thus, the prefer diamagnetic property of superconductors make then suitable for achieving frictionless motion in motors and hearing.

⇒ The phenomena of magnetic leviation is based on Meissner effect.

⇒ How to achieve magnetic leviation?

The magnetic leviation is brought about by enormous repulsion between two highly powerful magnetic fields.

If a small magnet is brought near a superconductor it will be repelled. This repulsion takes place due to the induced currents in the Superconductor which is being generated by the magnetic field of the magnet. Because of zero resistance property of the superconductor this current persists, and thus the field due to this induced current repels the field due to the magnet.

leviation of the magnet or maglev demostrates two critical properties of superconductors

i) Zero resistance and ii) Meissner Effect.

⇒ Magnetically leviated vehicles are called maglev vehicles. and it is such an arrangement great speeds could be achieved with very low energy consumption.

(i) Maglev Train:-

The leviation is based on two techniques

i) Electromagnetic suspension (EMS)

ii) Electrodynamic Suspension (EDS)

EMs the electromagnets installed on the train bogies attract the iron rails.

EDS leviation is achieved by creating a repulsive force between the train and guideways.

ii) A Similar magnetic propulsion system is being used to launch the stallite into orbits directly from the earth without the use of rockets.

Chapter-1 – Wave Motion and Sound

By: Dr. Manisha Vithalpura

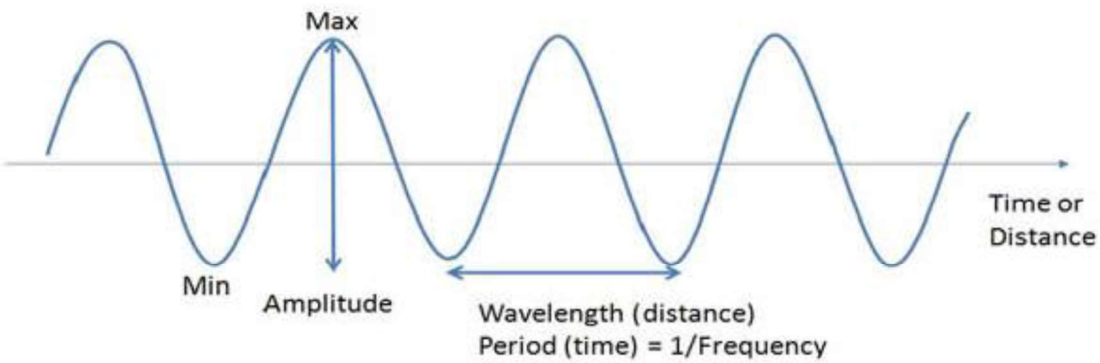
- Propagation of Waves
- Longitudinal and Transverse waves
- Introduction to Sound waves
- Characteristics and properties of sound waves
- Absorption Co-efficient
- Reverberation time
- Sabine's Formula (Without derivation)
- Factors affecting architectural acoustics
- Acoustic design of hall
- Noise pollution :its effect and remedies
- Introduction of Ultrasonic waves
- Generation of Ultrasonic waves
- Detection of Ultrasonic waves
- Applications of Ultrasonic waves: NDT, SONAR & others

INTRODUCTION

WAVES:

The oscillatory behavior of a particle due to perturbation/disturbance results in the formation of a wave. A common example of a wave is a wave on the ocean - we know they carry energy, as they cause erosion on the shore, but material (i. e., water) is not continuously being transferred onto the shore.

A simple type of wave is illustrated below.

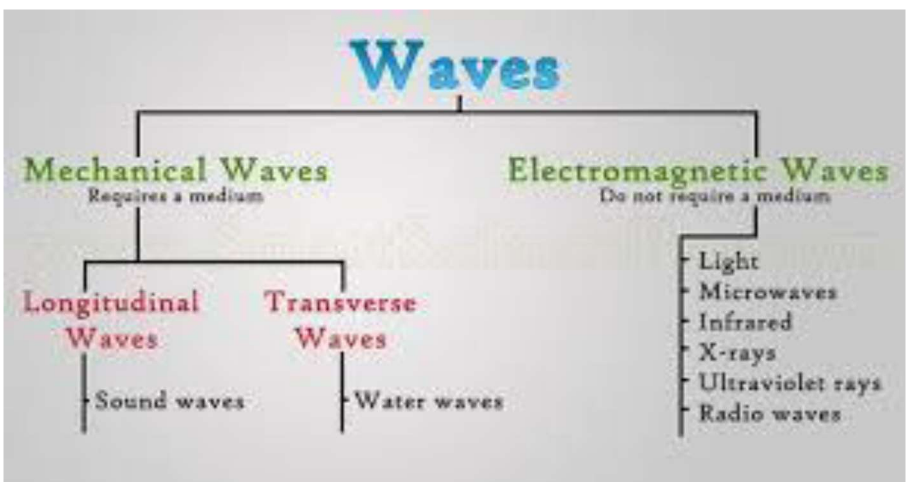


Frequency (f)– the number of cycles per second, measured in Hertz (Hz).
Period (P) – The time it takes for one complete wave to pass a given point, measured in seconds (the reciprocal of frequency (1/f)).

Wavelength (ƛ)– the length/distance between adjacent crests, measured in meters.
Amplitude (A)– the height of the wave. Equal to the (maximum-minimum)/2. For sound this is measured in decibels (dB) or pascals (Pa).
Propagation velocity (C)– how fast the wave is moving in the specific medium. Propagation velocity is dependent on the medium and is related to the stiffness of the medium.
Speed: the horizontal speed of a point on a wave as it propagates, measured in meters / second.

Waves can be classified mainly in two types :

1.Mechanical Waves:
2.Electromangenetic Waves:



Mechanical Waves are waves which propagate through a material medium (solid, liquid, or gas) at a wave speed which depends on the elastic and inertial properties of that medium.

WAVE MOTION:

The wave motion is one of the most important methods of transferring energy. Various forms of energies such as light, heat, sound, X-ray radiation, wireless, etc. are transmitted by wave motion. A wave motion can be defined as a disturbance which travels in the material medium and is due to the repeated periodic motion of the medium particles about their mean positions, the motion being handed on from one particle to the next after regular interval of time.

The propagation of the wave motion can take place only in the mediums which have the following properties:

(a) **Elasticity:** The medium must possess elasticity i.e. the medium particle must have tendency to return to its original position after being displaced.

(b) **Inertia:** The medium must have inertia i.e., it must have the capacity to store energy.

(c) **Little frictional resistance:** The medium must have only a very small frictional resistance to avoid dissipation of energy i.e., the frictional resistance should not be as large so as to cause damped vibrations of the medium particle.

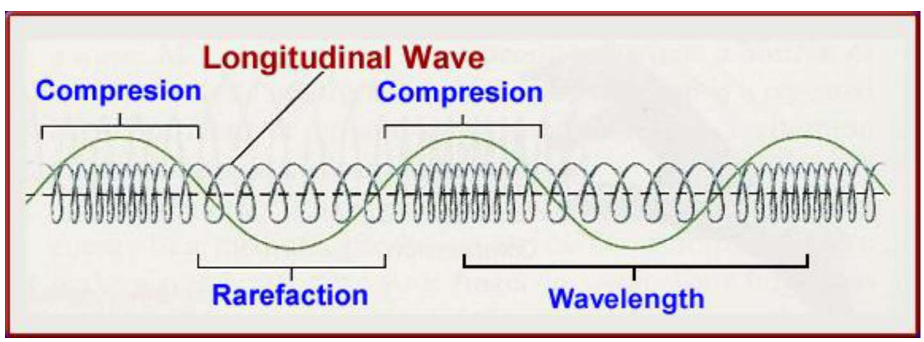
There are two basic types of wave motion for mechanical waves:

1. **Longitudinal waves**
2. **Transverse waves.**

1.Longitudinal Wave: A wave motion in which the particles of the medium vibrate about their mean position along the same line as that of propagation of the wave. Even though there are in the same direction, it is important to note that the particle does not move with wave, it merely oscillates in the same direction.

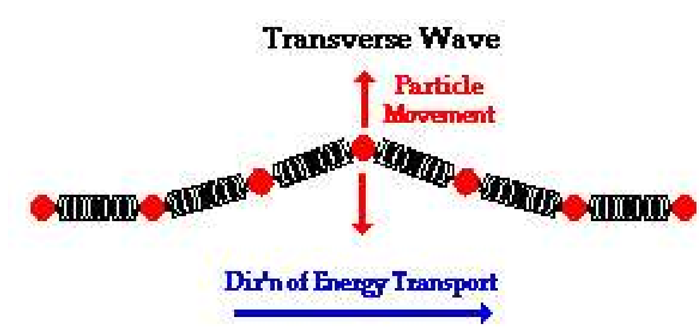
i.e. sound waves

In case of longitudinal waves the medium particles periodically approach or recede from one another forming alternate compressions and rarefactions in the medium



2.Transverse Waves: A wave motion in which the particle of the medium vibrate about their mean position at right angle to the direction of propagation of the wave. It is important to understand that an individual particles do not move from there original position on the horizontal axis, they merely oscillate vertically.

i.e. electromangnetic waves , waves on stings.



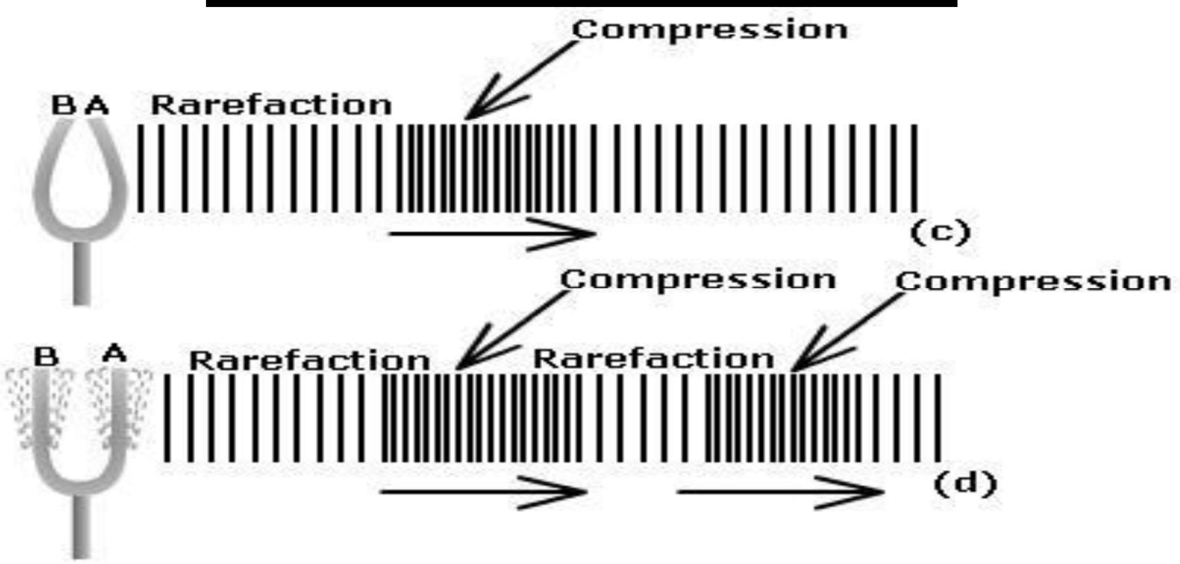
Acoustics

Prof. Wallace c. Sabine from Harvard university performed the systematic study about acoustic defects and presented sabines theory of reverberation to minimize acoustical defects and proposed precautions regarding the same.

Acoustics - Physics dealing with generation, propagation and applications of sound. Acoustics is the science of sounds which deals with the properties of sound waves.

Architecture of Acoustics- Physics dealing with construction of buildings with intention to provide good audible sound to the audience.

Soundwaves- Any vibrating body will displace the air layers nearby and initiate mechanical wave which propagates in the medium through alternate compression and rarefactions, sets the ear drum vibrating and causes the sensation of hearing.

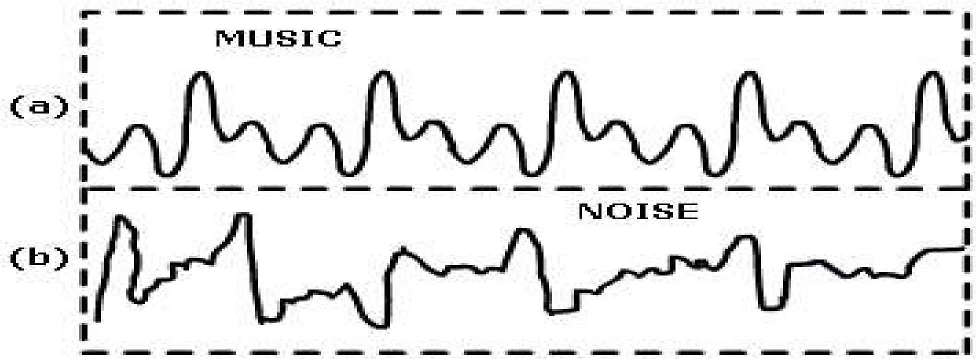


CLASSIFICATION OF SOUND:-

1. **Infra sound (< 20 Hz)**
2. **Audible sound (20 Hz – 20K Hz)**
3. **Ultra sound (>20K Hz)**

Classification of audible sound:-

(a). Musical Sound (b). Noise



Musical Sound: - The sound which produces pleasing effect on human ear is called noise.

Example: -sitar,violin,flute,piano, etc.

Properties of musical sound:

1. Regular wave forms
2. Definite periodicity
3. No sudden change in amplitude

Noise: - The sound which produces unpleasing effect on human ear is called noise.

Example: - road traffic,crackers, etc.

Properties of Noise:-

1. Irregular wave forms
2. Not definite periodicity
3. Sudden change in amplitude

CHARACTERISTICS OF MUSICAL SOUND:-

1. Pitch: - related to frequency of sound
2. Loudness:- related to intensity of sound
3. Timbre: - related to quality of sound

Definitions:

Pitch: - pitch is related frequency of sound. Pitch helps in distinguishing between a note of high frequency and low frequency sound of the same intensity produced by the same musical instruments.

This sound is produced by ladies and children with high frequency because of high pitch. This sound is produced by mosquito and bee with high frequency because of high pitch.

Loudness: -a loudness characteristic which is common to all sound, whether classified as musical sound or noise. Loudness is a degree of sensation produced on ear. Thus, loudness varies from listener to another. Loudness depends on intensity of sound and depends upon sensitiveness of the ear. Relation between loudness and intensity:-

$$L=K \log I$$

Loudness is directly proportional to the logarithm intensity I. Above relation is known as **Weber Fechner law.**

On taking differentiation of above relation so we get a new quantity $\frac{dL}{dI}$which is termed assensitiveness equation.

$$\frac{\mathbf{dL}}{\mathbf{dI}}=\frac{K}{I}$$

Where$\frac{dL}{dI}$ is called sensitiveness of the ear. Loudness is physiological quantity.

Timber: It is quality of sound which enables us to distinguishing between two sound having the same loudness and pitch. It depends on the presence of overtones.

It helps in distinguishing between musical notes emitted by different musical instruments and voice of the different persons even though the sounds have the same pitch and loudness.

Intensity (I):-

Intensity of sound waves at a point is defined as the amount of the sound energy Q flowing per unit area in unit time.

$$\mathbf{I=Q/At}$$

Where A=area, t=time , Q=amount of the sound energy

If A=1 m2 and t= 1 sec, then I=Q

Intensity is a physical quantity which depends on factors like amplitude, frequency and velocity v of sound together with the medium. The unit of intensity is $\frac{W}{m^2}$

Intensity level (Relative intensity):-

The Intensity level or Relative intensity of a sound is defined as the logarithmic ratio of the intensity I of a sound to the standard intensity I_0.

IL= K log (I/I0)

Let I and I0 represent of two sound of a particular frequency; and L_1 and L_0 is loudness.

Accordingto the**Weber Fechner law,**

$$L_1= K \log I$$

$$L_0= K \log I_0$$

Therefore, the intensity level or Relative intensity is

$$I_L= L_1-L_0$$

$$= K \log I - K \log I_0$$

$$= K (\log I - \log I_0)$$

$$I_L = K \log (I/I_0)$$

SOUND ABSORPTION COEFFICIENT 'a':-

The sound absorption coefficient 'a' of a material is defined as the ratio of sound energy absorption by material to the total sound energy incident on it.

$$Sound\ absorption\ coefficient\ = \frac{Sound\ energy\ absorbed\ by\ the\ surface}{Total\ sound\ energy\ incident\ on\ it}$$

A second form of the definition for absorption is given by **Sabine.** The unit of absorption co efficient is Sabine and is also called O.W.U. (open window unit)

REVERBERATION AND REVERBERATION TIME:

When a sound is produced in a building, it lasts too long after its production. It reaches to a listener a number of times. Once it reaches directly from the source and subsequently after reflections from the walls, windows, ceiling and floor of the hall. The listener, therefore, receives series of sounds of diminishing intensity.

Reverberation is meant the prolonged reflection of sound from the walls, floor and ceiling of a room. It is also defined as the persistence of audible sound after the source has stopped to emit sound.

The duration for which the sound persists is called reverberation time. This time is measured from the instant the source stops emitting sound.

The time of reverberation T is also defined as the time taken for the energy density to fall below the minimum audibility measured from the instant when the source stopped sounding.

Following expression for reverberation time T:

$$T= 0.165\ V/(\sum ads)$$

Where, V is the volume of the hall, a is absorption coefficient , ds is the area of sound absorbing materials

FACTORS AFFECTING ACOUSTICS Of BUILIDINGS AND THEIR REMEDIES:-

1. **Reverberation time**:- It is defined as the time during which the sound energy falls from its steady state value to 10-6 times after the source is cut off.

A sound produced in a volume is reflected multiple times from the various surfaces. As a result sound persists in the volume for some time of gradually decreasing intensity even the source stop emitting the sound. This persistence of the sound in a room due to multiple reflections, even when the source stops, is known as reverberation.

REMEDIES:-

1) By providing windows and opening.

2) By having full capacity of audience in the hall room.

3) By covering floor with carpets.

2. **Loudness**: **-** the uniform distribution of loudness in a hall or a room is an important factor for satisfactory hearing.

REMEDIES:-

1) By using public address system like loud speakers.

2) By using large sounding boards behind the speakers and facing the audience.

3. **Focusing and interference effects**:**-** the roll-call of any concave surface or any curve surface in a hall to make the sound to be connected at this regions. as a result the sound may be not heard at all at other regions. These regions are referred as dead space. Such surface must be avoided.

REMEDIES:-

1) Curved surface can be removed. If curved surface are present, they should be covered with a sound absorbing materials.

4. **Echo**: **-**An echo is heard due to reflection of sound from a distant sound reflecting object.

If the time travels between the direct sound and reflected sound is less than $1/15^{th}$ of a sound. The reflected sound is helpful in increases the loudness.

REMEDIES:-

1) An echo can be avoided by covering long distantance wall and ceilings with suitable a sound absorbing materials.

5. **Echelon effect**:**-** It refers to the generation of a new separate sound due to multi echo. A set of railings or any regular reflecting surface Is said to produce the echelon effect.

REMEDIES:-

1) Echelon effect should be avoided with good sound absorbing materials.

6. **Resonance: -** Resonance occurs due to the matching of frequency. If the window panels and wooden portion have not been tightly fitted, they start vibrating so some extra sound is produce so it called resonance.

REMEDIES:-

1) The resonance may be avoided by fitting window panels and wooden portion. Resonance can be placed by over sound absorbing materials.

7. **Noise: -** The unwanted sound is called noise. There are three type of Noise.

   1) Air-borne noise

   2) Structure borne noise

   3) Inside noise

   - **Air-borne noise:-** external noise which are coming from out side through open windows, doors are known as air-borne noise**.**

REMEDIES:-

1)The hall room can be made air conditioned.

2) By using good sound absorbing materials.

- **Structure borne noise: -** the noise which is conveying through the structure of the building is called structure borne noise.

REMEDIES:-

1) This noise can be eliminated by using double walls with air space between them.

2) By using anti vibration mounts this type of noise can be reduced.

3) By using good sound absorbing materials.

- **Inside noise: -**the noise which is produced in inside hall room is called inside noise. This noise is produced by generators,fans,typewriters, etc.

- **REMEDIES:-**

1) By using good sound absorbing materials.

2) By using curtains of sound absorbing materials.

3) By using covering the floor with good sound absorbing materials.

Condition for good Acoustics:-

1) The quality of a sound should be uniform throughout the entire hall.

2) There should be not over lapping sound.

3) The loudness of a sound should be uniform throughout the entire hall.

4) Resonance effect should be removed.

5) Echelon effect should be removed.

6) The hall should have proper reverberation time.

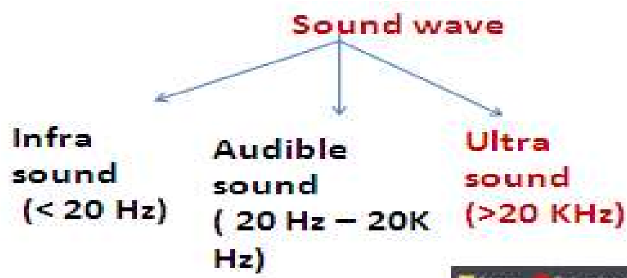
7) The external voice should not be disturbed in inside the hall.

Examples for Practice:

1. If the intensity of a source of sound is increased 20 times its value, by how many decibel does the intensity level increase? (Ans: 13.01 dB)
2. Calculate the intensity level of a plane just leaving the runway having sound intensity of about 1,000 Wm^{-2}. (Ans: 150 dB)
3. Calculate the intensity level in dB at a distance of 15m from a source which radiates energy at the rate of 3.56 W. The reference intensity is 100 Wm^{-2}. (Ans: -48.997dB)
4. What is the resultant sound level when a 70 dB sound is added to a 80dB sound? (Ans: 80.41dB)
5. What should be the total absorption in a hall of volume 10,000 m^3 if it is required to have a reverberation time of 1.4 sec? (Ans: 1192.85 sabine-m^2)
6. The volume of a room is 1,200m^3. The wall area of the room is 220m^2, the floor area is 120m^2 and the ceiling area is 120m^2. The average sound absorption coefficient (i) for walls is 0.03; (ii) for the ceiling is 0.80; and (iii) for the floor is 0.06. Calculate the average sound absorption coefficient and the reverberation time. (Ans: a = 0.2386 sabine, T= 1.825 sec.)

7. A hall has a volume of 2,265 m^3. Its total absorption is equivalent to 94.85 m^2 of open window. What will be the effect on reverberation time if the audience fill the hall and thereby increase the absorption by another 94.85m^2?

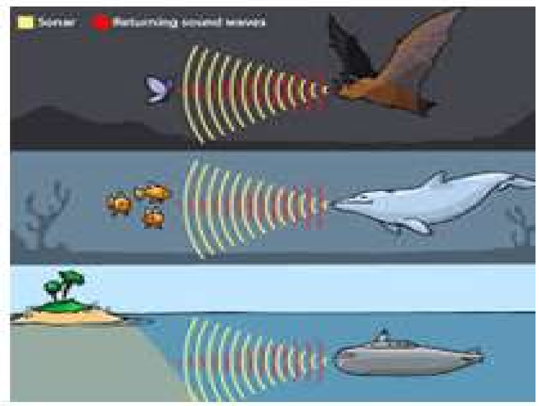
Ultrasonic

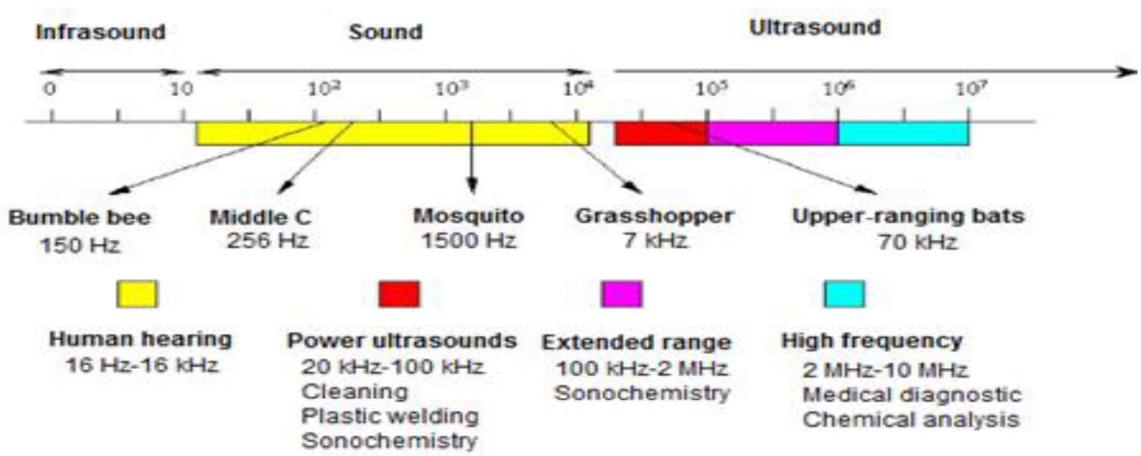


ULTRASONICS

Introduction:

The sound wave which is having frequency greater than 20 KHz(> > 20 KHz) called Ultrasonic wave.





Properties of Ultrasound:

- Frequency is greater than 20KHz and highly energetic beam.
- Their speed of propagation depends upon their frequency, i.e., increases with increase in frequency. It can propagate long distance because of its high frequency
- It can travel with constant speed in homogeneous medium. It cannot travel in vacuum.

- They show negligible diffraction due to their small wavelength. Hence they can be transmitted over long distances without any appreciable loss of energy.
- Intense ultrasonic radiation has a disruptive effect in liquids by causing bubbles to be formed.

Production of Ultrasonic Waves

The Ultrasonic waves cannot be produced by our usual method of a diaphragm loudspeaker fed with alternating current. This is due to the fact that at very high frequencies the inductive effect of the loudspeaker coil is so large that practically no current passes through it. Moreover, the diaphragm of a loud speaker can not vibrate at such high frequencies. Hence other methods are used for the production of ultrasonic waves. There are two important methods namely magneto-striction method and Piezoelectric method which are mostly used now a days.

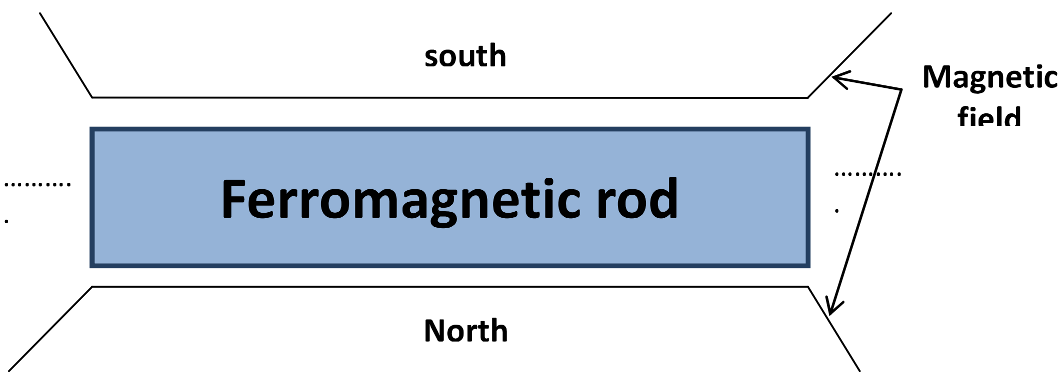
1. Magnetostriction Method

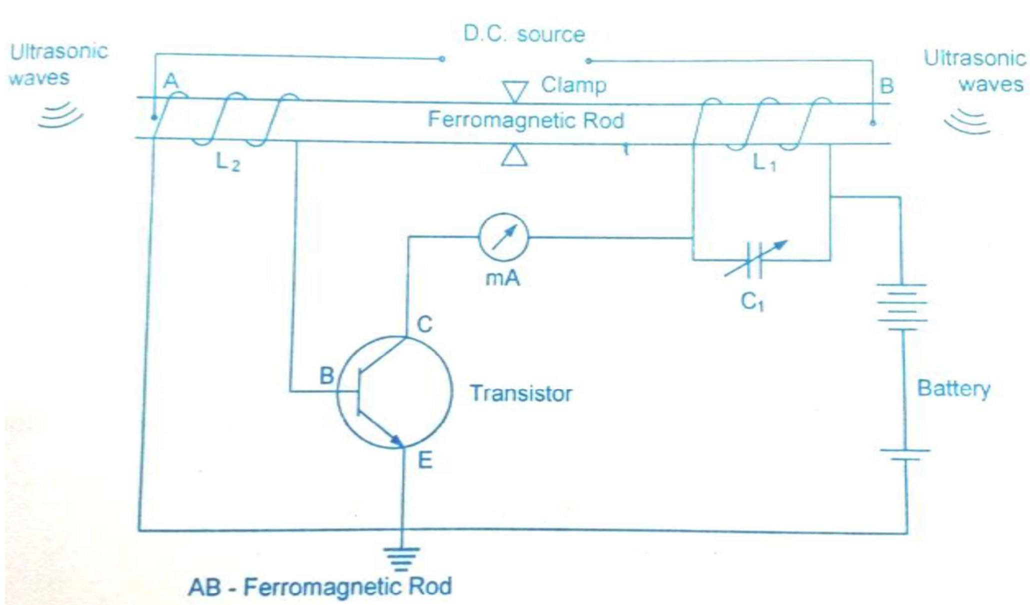
It is used to produce ultrasonic waves

Magnetostriction Effect:

When alternating magnetic field is applied parallel to ferromagnetic rod like iron, nickel etc. it experiences contraction and expansion at same frequency as of applied magnetic field. This Effect is known as "Magnetostriction Effect".

- Materials which are used to produce ultrasonic waves are known as Magnetostriction materials.





Construction:

- There is a short nickel rod which is clamped at the centre. This rod is permanently magnetized in the beginning by passing a direct current in the coil which is wrapped round the rod.
- Two ends of the rod are wounded by coils, L_1 and L_2 coil. The coil L_1 is connected to the collector output of the transistor and the coil L_2 is connected to the base of the transistor as shown in fig. To the coil L_1 a variable capacitor C_1 is connected in parallel and this forms the tank or resonant circuit.

Working:

- when the battery is switched on, the resonant circuit L_1C_1 sets up an alternating current of frequency,

$$f = \frac{1}{2\pi\sqrt{L_1C_1}}$$

- As a result, the rod gets magnetised by the plate current, Any change in the plate current brings about a change in the magnetisation and consequently a change in the length of the rod. This gives rise to a change in flux in coil L_2 , thereby inducing an emf in the coil L_2 . This varying emf, thereby maintaining the oscillations. By varying capacitor C_1, the frequency of oscillation of the tank circuit gets varied. If the frequency of the tank circuit matches with the natural frequency of the material, then due to the resonance the rod vibrates and produce ultrasonic waves at the ends of the rod.
- The vibrational frequency of the material of length l, density ρ and elastic constant E of the rod is

$$f = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

When the frequency of the circuit becomes equal to the frequency of the rod, resonance occurs and the sound waves of maximum amplitude are generated.

Merits:

- very simple oscillator and production cost is low.
- At low Ultrasonic frequency, large o/p power is possible
- frequency ranging from 100 Hz to 3000KHz can be produced

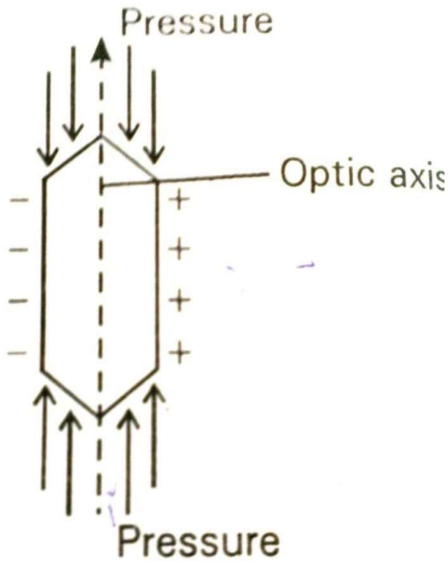
Demerits:

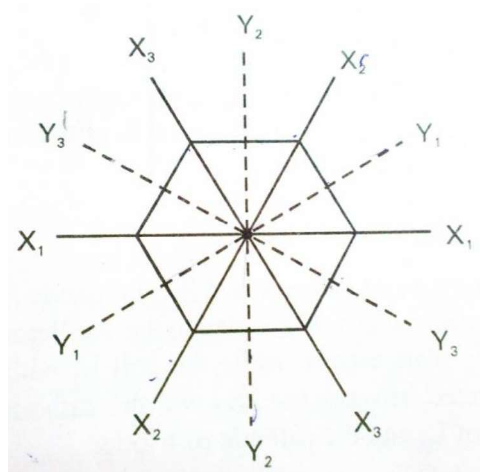
- can not generate ultrasonic wave of frequency above 3000 KHz.
- The Frequency of oscillations depends greatly on temperature.
- There will be losses of energy due to hysteresis and eddy current.

2. Piezo-electric Method:

Piezoelectric effect:

when pressure is applied to one pair of opposite faces of crystals like Quartz, tourmaline, rochelle salt etc, cut with their faces perpendicular to its optic axis, equal and opposite charges appear across its other faces as shown in fig. this is known as piezoelectric effect.

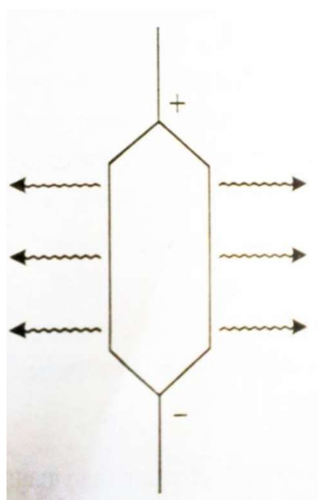


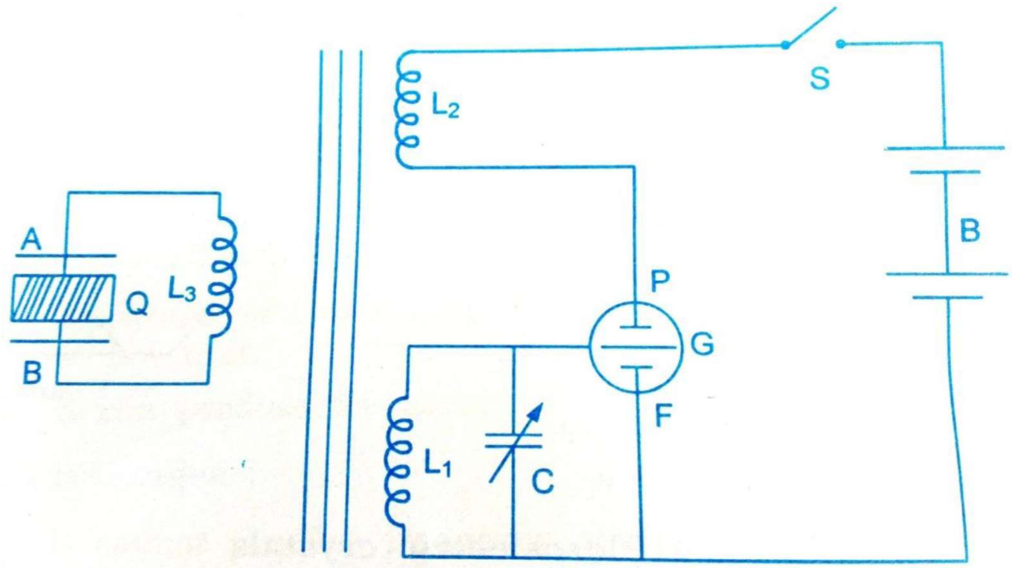


Inverse piezoelectric effect:

If an alternating voltage is applied to one pair of opposite faces of the crystal, alternatively mechanical contractions and expansions are produced in the crystal and the crystal starts vibrating. This effect is known as **inverse piezoelectric effect** or **electrostriction effect**.

- When the frequency of the applied alternating voltage is equal to the vibrating frequency of the crystal, then the crystal will produce ultrasonic waves.





The experimental arrangement is shown in fig. Quartz crystal Q is placed between two metal plates A and B, connected to the coil L_3. The coil L_1, L_2 and L_3 is connected to triode valve. Coil L_1 is connected parallel with variable capacitor C_1 forming the tank circuit. The high tension battery is connected between free end of L_2 and the cathode of triode.

Working:

- When high tension battery is switched on, the oscillator produces high frequency alternating voltage given by

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

- The f of oscillation can be controlled by the variable capacitor C_1.
- Due to the transformer action an emf is induced in the secondary coil L_3. This emf are impressed on the plates A and B , will excite the quartz crystal into vibrations.
- By adjusting the variable capacitor C_1, frequency can be achieved in resonant conditions and crystal will produce ultrasonic waves. The frequency of vibrations is

$$f = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

Where, E is Young's modulus, ρ is the density of the material, l is length.

Merits:

- More efficient
- frequency can be achieved up to 5 x 108 Hz
- o/p of this oscillator is very high.
- not affected by temperature and humidity

Demerits:

- cost is high and crystal's cutting and shaping are very complex.

Detection of Ultrasonics:

We cannot directly detect the ultrasonic although some animals specially the bat can do so. However, the ultrasonic can be detected by the following methods:

1. **Kundt's tube method:**

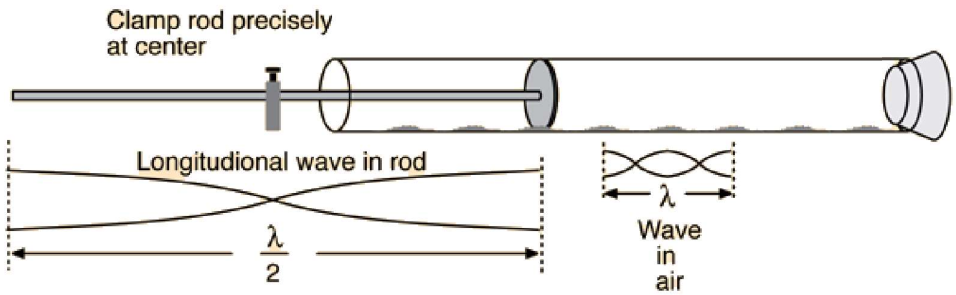
- restricted to low frequency waves

- when ultrasonic wave go through the glass tube filled with **hycopodium powder** sprinkled in the tube, the powder gets blown off and forms heaps at nodal points

- the distance between any two nodes is equal to half of the wavelength.

$$D = \lambda us/2$$

- wavelength of ultrasonic wave is estimated from above equation.



2. **Thermal detector method:**

- Often used
- a fine platinum wire is moved through the medium. Due to compressions and rarefactions, the temperature changes at the nodal points and resistance of the wire will be changed at that point whereas it will remain constant at the antinodes. The change in the resistance of platinum wire with respect to time can be detected by using a sensitive bridge arrangement. The bridge will be in the balanced position when the platinum wire is at antinodes.

3. **Sensitive flame method:**

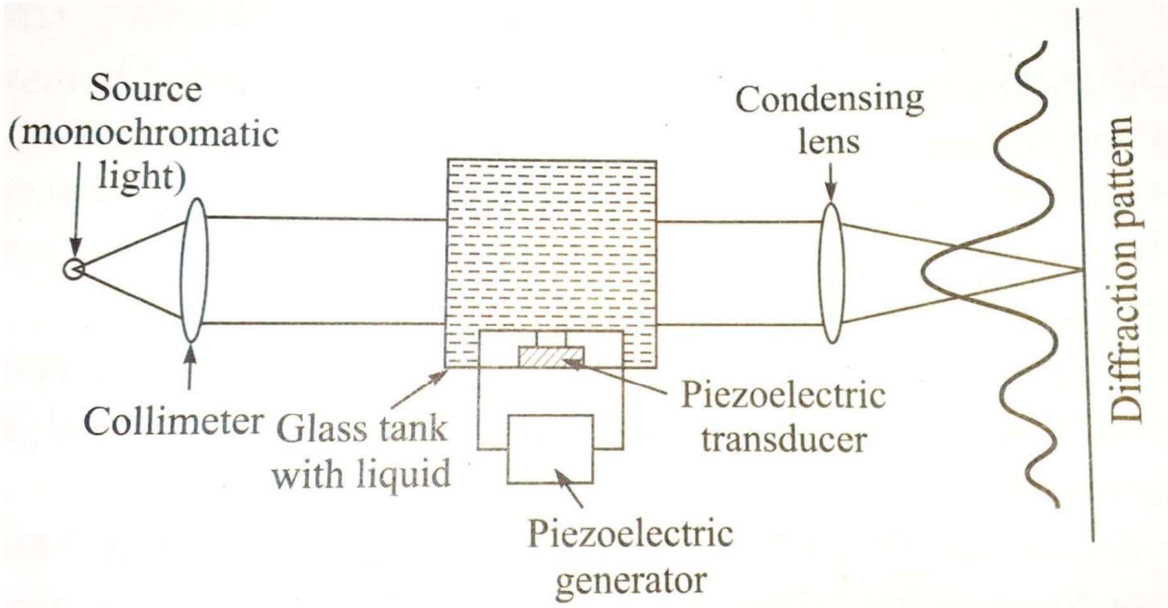
- Ultrasonic waves are detected by moving a sensitive flame in the medium.
- At nodes points the flame will flicker and at the antinodes it will remain stationary.
- By knowing the mean distance between two consecutive nodes, the ultrasonic wavelength can be determined as usual.

4. **Quartz Crystal method:**

- This method depends upon the piezoelectric effect.
- when one pair of faces of a quartz crystal is exposed to ultrasonic waves, electric charges are developed on the other pair of opposite faces which are perpendicular to the previous one.
- these charges are amplified and detected by using electric circuits.

Determination of wavelength and velocity of ultrasonic waves in liquids:

- The phenomenon of diffraction of light by ultrasonic waves passing through a liquid was first observed by Debye and Sears in America in 1932.



- Ultrasonic waves are generated and propagate through the liquid medium by compression and rarefaction, the density varies from layer to layer due to periodic variation in pressure. The change in density of the liquid in turn leads to a variation in the refractive index of the liquid. The density of the liquid will be maximum at nodal planes, while at the antinodal planes the density of the liquid will be minimum. Such a liquid column subjected ultrasonic waves behaves like a grating. Under this condition, if a parallel beam of light is passed through this medium, the liquid behaves like a diffraction grating. This is known as ' Acoustical grating'.
- **Experiment:**
- In this liquid tank ultrasonic quartz is kept which produces ultrasonic waves. Due to the reflection of ultrasonic waves from surface of the tank, stationary wave is formed in the liquid. Then light from monochromatic source is collimated with the help of two lenses and can be passed through the liquid column which is in the direction perpendicular to the liquid column. We can observe maxima and minima pattern due to diffraction of light and distance between two consecutive maxima can be measured with telescope.
- distance between two consecutive maximas or minimas is 'd' then wavelength of light can be given by,

$$d \sin \theta = n\lambda$$

- Here, n is the order of maxima or minima and θ is angle of diffraction.
- For the first maxima, n=1 and θ =90°
- So wavelength (λu) , $\lambda u = 2d$
- So, $\lambda u = 2n\lambda / \sin \theta$
- Where, λ is wavelength of monochromatic light.
- If f is frequency of ultrasonic wave then velocity of ultrasonic in liquid can be given by,

$$V = f \lambda u$$

- Using this acoustic diffraction method, the wavelength and hence the velocity of ultrasonic waves through liquids and gases at various temperatures can be determined.

<u>Applications:</u>

Science and Engineering:

- Used to detect flaws or cracks in metals
- used to detect ships, submarines, iceberg etc. in ocean
- used for soldering aluminium coil capacitors, aluminium wires and plates without using any fluxes.

- used for cutting, drilling holes and welding of metals
- used as a catalytic agent and accelerate chemical reactions
- also used to inspect any object without damage which is called Non Destructive Testing.

Medicine:

- Used to remove kidney stones and brain tumours without sheddng any blood
- used to remove broken teeth
- used for sterilising milk and to kill bacteria
- used to study the blood flow velocities in blood vessels of our body
- used for diagnostic tool to detect tumours and for cancer treatment.
- It is also used to find the depth of the sea through SONAR technique.

SONAR (Sound Navigation and Ranging):

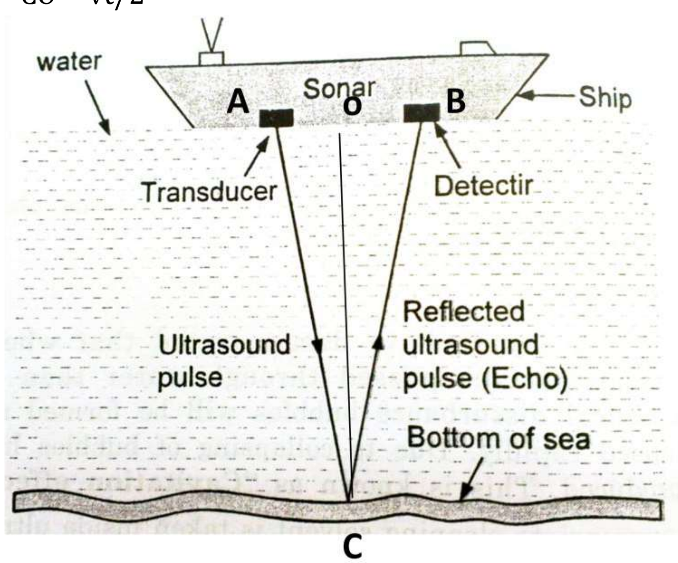
It is possible to determine the presence of submerged submarines or an enemy aircraft by a system known as SONAR. Sonar is a device which stands for Sound Navigation and Ranging.

Because of the properties of ultrasonic wave, Depth of the sea and any obstacles can be identified with the help of SONAR.

- In this system, Transmitter of SONAR will transmit the ultrasonic rays in various directions into the sea. These rays will get reflected back when it gets hited to any obstacles. This reflection will be picked up by receiver. By measuring distance and time of transmitted and reflected waves, the velocity of ultrasonic wave is calculated.
- distance travelled by transmitted and reflected wave is $AC + BC$

velocity $v = AC + BC/t$, so $v = 2\ CO/t$,

So depth of sea is $CO = vt/2$



NDT (Non Destructive Testing)

It is a method to inspect any object without damage

Ultrasonic NDT:

- It is used to inspect flaw or any defects inside metals, castings, welding, etc.
- High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws.
-
- The time and intensity of that reflected waves will describe magnitude of flaw and its location.

Advantages:

- Provides high accuracy in determining position of reflector and estimating size and shape

- can also be utilized for other uses such as thickness measurements, and flaw detection.

Disadvantages:

- Material surface must be accessible to transmit ultrasound
- Rough , irregular shaped, very small , non homogeneous materials are difficult to inspect

Examples: (for Practice)

1. **Calculate thickness of a quartz plate designed to produce ultrasonic waves at 1st mode of vibration with the frequency of 3 MHz. Young's modulus of quartz crystal is 85 Gpa and density of material is 2650 kg/m3.**
2. **Calculate frequency of ultrasonic waves which can be generated by a nickel rod having length of 5 cm. Here, young's modulus of nickel is 207 Gpa and its density is 8900 kg/m3. (Ans. : 48.22 KHz)**
3. **An ultrasonic source of 0.07 MHz sends down a pulse towards the sea bed, which returns after 0.65 Sec. The velocity of sound in sea water is 1700 m/s. Show that the depth of sea is 552.5 m and the wavelength of pulse is 0.0242 m.**
4. **Calculate the inductance to produce ultrasonics of 106 Hz with capacitance of 0.025 μF.**