OBJECTIVES

1) To explore the knowledge on high frequency sound waves and their applications
2) To study the different methods of production and detection of ultrasonic waves
3) To study the characteristic properties of ultrasonic waves
4) To study the applications of ultrasonic in industry, medicine and other areas.

REAL - LIFE APPLICATION

1) Obtaining the first glimpse of a child in a mother's womb
2) Measuring the depth of the ocean
3) Non- destructive testing of mechanical parts

4.1 Characteristics of Sound

- Sound is a form of energy.
- Sound is produced by the vibration of the body.
- Sound requires a material medium for its propagation and can be transmitted through solids, liquids and gases.
- When sound is conveyed from one medium to another medium there is no bodily motion of the medium.
- Sound requires a definite interval of time to travel from one point to another point in a medium and its velocity is smaller than the velocity of the light.
- Velocity of sound is maximum in solids, which have higher bulk modulus and least in gases.
- Sound may be reflected, refracted, or scattered. It exhibits diffraction and interference. In transverse mode it exhibits polarization also.

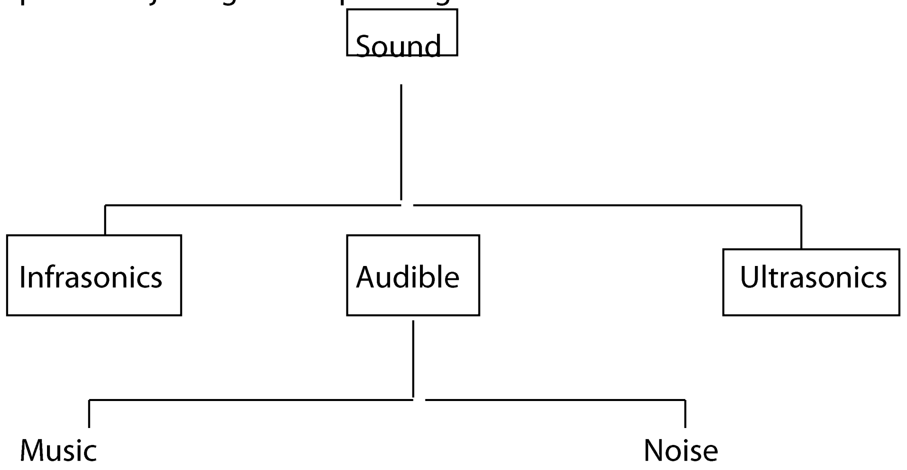
4.2 Classification of Sound

i. Sound waves of frequencies below 20 Hz are termed as Infrasonic (inaudible)

ii. Sound waves of frequencies above 20000 Hz are termed as Ultrasonic (inaudible)

iii. Sound waves of frequencies 20 Hz to 20,000 Hz are termed as audible sound

Further the audible sound is classified as Musical Sounds and Noise . the sounds which produces effect on the ear are called musical sound and that which produces jarring and unpleasing effect are called noises.



4.2.1 Characteristics of Musical Sound

There are three characteristics of Musical Sound

i. Pitch or Frequency
ii. Quality or Timbre
iii. Intensity or Loudness

a. **Pitch or frequency** :

Pitch is the characteristic of sound which is the sensation conveyed to our brain by the sound waves falling in our ears. It depends directly on the frequency of the incident sound waves. Though the pitch is directly related to frequency, they are not the same; in general the frequency is a physical quantity whereas the pitch is a physiological quantity.

Example: sound of mosquito produces high pitch than the sound of lion which is a low pitch.

b. Quality or Timbre

The quality of the sound is the one which helps us to distinguish between the musical notes emitted by the different instruments or voices, even though they have the same pitch and loudness.

c. Intensity or loudness

The intensity of sound at a point is defined as the average rate of flow of acoustic energy (Q) per unit area situated normally to the direction of the propagation of sound wave.

$$I = \frac{Q}{A}$$

The intensity depends upon the following factors

$$I \propto \frac{n^2 a^2 \rho \upsilon}{x^2}$$

Where n = Frequency of the sound wave

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 or Intensity per unit area per unit time $I = 2\pi^2 a^2 n^2 \rho \upsilon$

4.2.2 Loudness – Weber Fechner Law

Loudness of the sound is defined as the degree of sensation produced on the ear. The loudness varies from one observer to another. It is a physiological quantity and therefore it is difficult to measure loudness. But, it can be measured a logarithmic value of intensity

$$L \propto LogI$$

$$L \propto KLogI \longrightarrow 1$$

Equation 1 is known as WEBER – FECHNER law.

Differentiating equation 1, we have

$$\frac{dL}{dI} = \frac{k}{I}$$

Where $\frac{dL}{dI}$ is called Sensitiveness of ear. Therefore the sensitiveness decreases with the increase in Intensity. For example more sound in an auditorium will not be hard properly.

S.NO	INTENSITY	LOUDNESS
1.	It refers to the external measurement	It is just a sensation produced on the ear.
2.	It is common to hear	It depends upon individual listener
3.	It can be measured directly	It is measured only with respect to intensity.

4.2.3 UNIT OF LOUDNESS

If L_1 is the Loudness of sound of intensity I_1 and L_0 is the loudness corresponding to the standard reference intensity $I_0 = 10^{-12}$ watts/m^2, then according to Weber – Fechner law, we have

$$L_1 = k \log_{10} I_1$$

And $$L_0 = k \log_{10} I_0$$

Now , the intensity level(I_L) which is equal to the difference in Loudness,

$$I_L = L_1 - L_0 = k \log_{10} I_1 - k \log_{10} I_0$$

$$I_L = k \log_{10} \frac{I_1}{I_0}$$

If k is taken as 1 , the intensity level or difference in loudness is expressed in bels, a unit named after Alexander Graham Bell, the inventor of Telephone

$$I_L = 1 \times \log_{10} \frac{I_1}{I_0} bel$$

4.2.4 **Decibel**

The unit of Bel is however quite large and hence I_L is expressed by another standard unit called decibel 1 bel = 10 decibels.

$$I_L = 10 \times \log_{10} \frac{I_1}{I_0} dB \longrightarrow \quad 1$$

Case 1.

If I_L= 0dB, then equation 1 becomes

$$I_L = \log_{10} \frac{I_1}{I_0} or \frac{I_1}{I_0} = 10^0$$

$$or \frac{I_1}{I_0} = 1 \longrightarrow \quad 2$$

Case 2:

If I_L= 1dB, then equation 1 becomes

$$I_L = \log_{10} \frac{I_1}{I_0} = \frac{1}{10} or \frac{I_1}{I_0} = 10^{\frac{1}{10}}$$

$$\therefore \frac{I_1}{I_0} = 1.26 \longrightarrow \quad 3$$

Subtracting equation 2 from 3, we get

1.26-1= 0.26

∴ For a change in intensity level of 1 dB, the intensity changes to about 26%.

∴ When $I_1 = 100\ I_0$; $I_L = 20dB$

When $I_1 = 1000 I_0$; $I_L = 30dB$

To build up a scale of loudness, zero on the scale is taken as the threshold of hearing, which corresponds to $I_0 = 10^{12} W/m^2$. The maximum intensity with which an ear can tolerate is $I = 1 W/m^2$.

The maximum intensity level an ear can hear is

$$I_L = 10 \log_{10} \frac{1}{10^{-12}} dB$$

$$= 120 dB$$

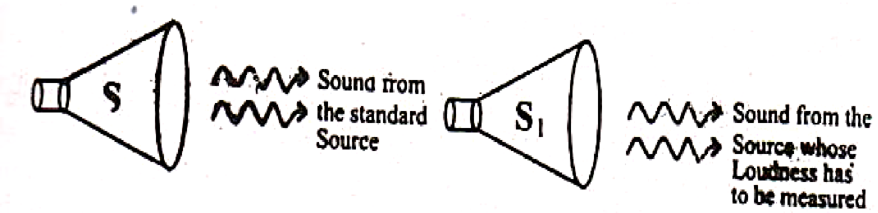
S.NO	SOURCE	INTENSITY LEVEL IN dB
1.	Threshold of hearing	0
2.	Rustle of leaves	10
3.	Whisper	15-20
4.	Average house	40
5.	Ordinary conversation	60-65
6.	Motors or heavy traffic trucks	70-80
7.	Roaring of lion at 20 feet	90
8.	Thunder	100-110
9.	Painful sound	120 and above

4.2.5 PHON

We have expressed the loudness in dB, on the assumption that the threshold of audibility is constant for all frequencies. But it is found that the threshold of audibility varies with frequency. Sounds of same intensity but of different frequency differ in loudness. Hence a different unit called PHON is used to measure loudness level or equivalent loudness.

Definition: The measure of loudness in Phons of any sound is equal to loudness in decibels of an equally loud pure tone of frequency 1000Hz.

Explanation: Let us consider tow sources 'S' the standard source and S_1, the source of sound for which loudness is to be measured. The two sounds are heard alternatively and the intensity of S is adjusted to be equal to the loudness of the S_1 as shown in the figure.



Now the intensity level of S is measured, if it say 'n' decibels above the standard intensity, then the equivalent loudness is 'n' Phons

The expression for loudness in Phon (L_P) is given by

$$L_P = 10 \log \frac{I}{I_0}$$

Here $I_0 = 10^{-12}$ W/m^2.

$$\therefore L_P = 10 \log I - 10 \log 10^{-12}$$

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

Where I is the intensity of sound in dB.

4.2.6 SONE

Sone is another unit to measure the loudness in terms of Phon or dB. It is used to measure very high loudness, especially between the ranges of 40 Phons to 100 Phons.

i. SONE in terms of PHON

Definition: The measure of loudness in some of any sound is equal to the loudness of that particular sound having a loudness level of 40 PHons.

Explanation: Suppose a source of sound is having the loudness or 40 Phons then it can be assumed to have a loudness of 1 Sone.

Expression for Loudness in Sone is empirically given by

$$\log L_S = 0.333 (L_P - 40)$$

L_S = Loudness in Sone

L_P = Loudness in Phon

Example:

Suppose if the loudness in Phon is 40 Phons, then the loudness in Sone is given by

$$\log L_S = 0.033(40 - 40)$$
$$\log L_S = 0$$
$$L_S = 10^0$$
$$L_S = 1 Sone$$

ii. Sone in terms of Decibel

Definition: In terms of decibels the Sone is defined as the loudness of an equally loud pure tone of frequency 1000Hz with 40dB if intensity level.

Explanation: It is similar to that of the measurement of loudness in Phon in terms of dB, but the increase in intensity level should be 40dB above the standard intensity, then the equivalent loudness is 1 Sone.

We know that

$$\log L_S = 0.333(L_P - 40)$$

Substituting for $L_P = 10 Log I + 120$, we get

$$\log L_S = 0.033(10 \log I + 120 - 40)$$
$$\log L_S = 0.033(10 \log I + 80)$$
$$\log L_S = 0.33 \log I + 2.64$$
$$\log L_S = \log (I^{0.33})(10^{2.64})$$
$$L_S = (I^{0.33}) 436.5$$
$$L_S = 437(I^{0.33})$$

L_S = Loudness in Sone

I = Intensity of Sound in dB.

4.3 Acoustics of buildings

In day today life sound engineering plays a vital role in film industries, broadcasting of television signals and even in television signals. So a new field of science is developed which deals with the planning of a building or a hall with a view to provide best audible sound to the audience and is called Acoustics of building. Therefore to provide a best audible sound in a building or hall a prime factor called Reverberation

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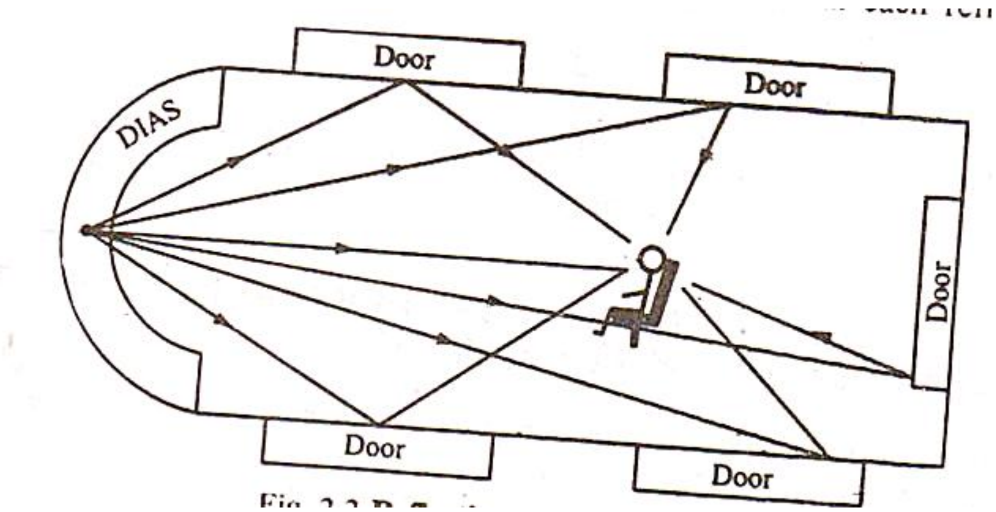
4.3.1 REVREBERATION



When a sound pulse is generated in a hall, the sound wave travels towards all direction and are reflected back by the walls, floors, doors, windows ceiling etc as shown in the figure.

So a sound wave has two to three hundred repeated reflections, before it becomes inaudible. Therefore, the observer in the hall does not be able to hear a single sharp sound instead a "role of sound" of diminishing intensity (since part of energy is lost at each reflection)

4.3.2 Reverberation time

The duration for which the sound persist is termed as reverberation time and is measured as the time interval between the sound produced by the source produced by the source and to the sound wave until it dies.

Definition:

It is defined as the time taken for the sound to fall below the minimum audibility measured from the instant when the source sound gets stopped.

In designing the auditorium, theatre, conference halls etc, the reverberation time is the key factor.

If the reverberation time is too large, echoes are produced and if the reverberation time is too short it becomes inaudible by the observer and the sound is said to be dead. Therefore the reverberation time should not be too large or too short rather it should have an optimum value.

In order to fix this optimum value standard formula is derived by W.C.Sabine, who defined the standard reverberation time as the time taken for the sound to fall to one millionth of its original intensity just before the source is cut off.

$E = \frac{E_m}{10^6}$ Where E is the energy or intensity of sound at any time't'

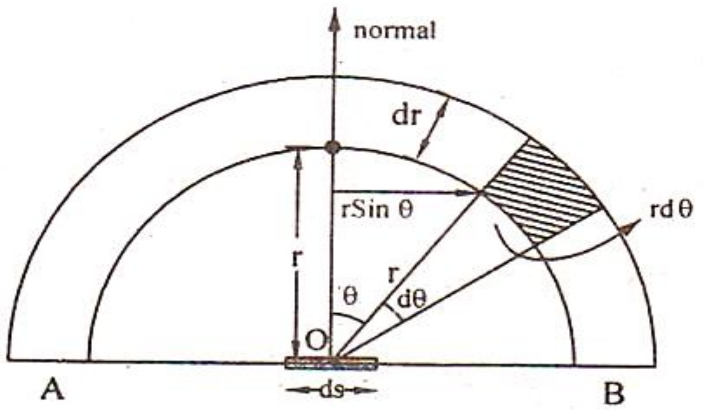
E_m = the maximum sound energy produced originally

4.3.3 SABINES FORMULA FOR REVERBERATION

The relation connecting the reverberation time with the volume of the hall, the area and the absorption coefficient is known a s Sabine's Formula.

Sabine's developed the formula to express the rise and fall of sound intensity by the following assumptions.

i. Distribution of sound energy is uniform throughout the hall
ii. There is Interference between the sound waves.
iii. The Absorption coefficient is independent of sound intensity.
iv. The Rate of emission of sound energy from the source is constant.



Let us consider a small element 'ds' on a plane wall AB. Assume that the element ds receive the sound energy 'E'.

Let us draw two concentric circles of radii 'r' and r + dr from the center point 'O' of ds. Consider a small shaded portion lying in between the two semi circles drawn at an angle $\theta and \theta + d\theta$, with the normal to ds as shown in the figure.

Let 'dr' be th radial length and rdθ be the arc length

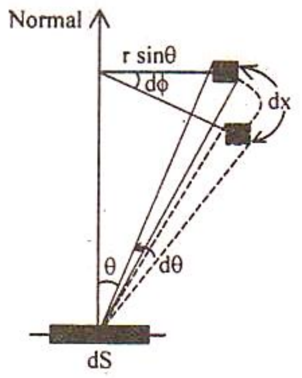
Area of shaded portion $rd\theta.dr$ ⟶ 1

If the whole figure is rotated about the normal through an angle 'dϕ' as shown in the figure , then it is evident that the area of the shaded portion travels through a small distance dx.

$$dx = r\sin\theta . d\phi \longrightarrow 2$$

Therefore Volume of the shaded portion is

dV = Area× distance



Substituting from equation 1 and 2 we have

$$dV = rd\theta dr.r\sin\theta d\phi$$

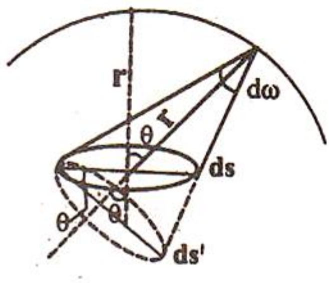
$$dV = r^2\sin\theta dr.d\theta d\phi$$

∴ The sound energy present in this volume

$$dV = E\times volume$$

$$dV = Er^2\sin\theta dr.d\theta d\phi$$

This sound energy will travel through the element in all directions.



∴ The sound energy present in this volume dV per unit solid angle is

$$dV = \frac{Er^2\sin\theta dr.d\theta d\phi}{4\pi}$$

∴ In this case the solid angle subtended by the area 'ds' at this element of volume 'dV' is

$$d\omega = \frac{ds'}{r^2}$$

From figure we can write

$$\cos\vartheta = \frac{ds'}{ds}$$

$$ds' = ds\cos\theta$$

Therefore we can write solid angle subtended by the area 'ds' as

$$d\omega = \frac{ds'}{r^2} = \frac{ds\cos\theta}{r^2}$$

Hence, the sound energy travelling from the element (i.e., from dw to 'ds')

$$= \frac{Er^2\sin\theta dr.d\theta d\phi}{4\pi}\frac{ds\cos\theta}{r^2} \longrightarrow 3$$

To find the total energy received by the element 'ds' per second, we have to integrate the equation 3 for the whole volume lying within a distance 'v' is the Velocity of Sound

It is obvious from the geometry of the figure that,

ϕ Changes from 0 to 2π

θ Changes from 0 to $\pi/2$

r Changes from 0 to v

$\therefore$ Integrating equation 3 with respect to these lines, we can write

Energy received per second by ds = $\dfrac{Eds}{4\pi}\int_0^v dr\int_0^{\frac{\pi}{2}}\sin\theta.\cos\theta.d\theta\int_0^{2\pi}d\phi$

$$=\frac{Eds}{4\pi}2\pi\int_0^v dr\int_0^{\frac{\pi}{2}}\sin\theta.\cos\theta.d\theta$$

$$=\frac{Eds}{2}\int_0^v dr\int_0^{\frac{\pi}{2}}\sin\theta.\cos\theta.d\theta$$

Multiply both numerator and denominator by 2 we get

$$=\frac{Eds}{4}\int_0^v dr\int_0^{\frac{\pi}{2}}2\sin\theta.\cos\theta.d\theta$$

$$=\frac{Eds}{4}\int_0^v dr\int_0^{\frac{\pi}{2}}Sin2\theta.d\theta$$

$$=\frac{Eds}{4}\int_0^v dr \qquad \because \int_0^{\pi/2}Sin2\theta=1$$

$$=\frac{Eds}{4}v \longrightarrow \qquad 4$$

Let 'a' be the absorption coefficient of the area 'ds'.

$\therefore$ The energy absorbed by ds in unit time = $\dfrac{Evads}{4}$

$\therefore$ The total absorption at all the surfaces of the wall is $\frac{1}{4} Ev \sum a.ds$

$\therefore$ Total rate of Energy absorption = $\frac{1}{4} EvA$ ⟶ 5

Where 'E' is the energy from sources and 'A' is the total absorption on all surfaces on which the sound falls $A = \sum a.ds$

4.3.3.1Growth and Decay of Sound Energy

If 'P' is the Power Output (i.e., the rate of emission of sound energy from the source) then we can write

Rate of Emission of Sound energy i.e., Power Output $P = \frac{1}{4} E_m vA$

Here E_m is the maximum energy from the source (which has been emitted) that is maximum energy which is incident on the wall

$$\therefore E_m = \frac{4P}{vA} \longrightarrow \quad 6$$

If V is the volume of the hall we can write the total energy at any instant't' = EV

$\therefore$ Rate of Growth or Increase in energy = $\frac{d}{dt}(EV) = V\frac{dE}{dt}$ ⟶ 7

At any instant

Rate of Growth of Energy	=	Rate of Supply of Energy from the source	-	Rate of absorption of energy by walls

$\therefore$ From equation 5 and 7 we can write

$$V.\frac{dE}{dt} = P - \frac{1}{4} EvA$$

$$\frac{dE}{dt} = \frac{P}{V} - \frac{EvA}{4V}$$

Let $\alpha = \frac{vA}{4V}$

$$\frac{dE}{dt} = \frac{4P}{vA}\alpha - \alpha E$$

$$\frac{dE}{dt} + \alpha E = \frac{4P}{vA}\alpha$$

Multiplying by $e^{\alpha t}$ on both sides, we have

$$\left(\frac{dE}{dt} + \alpha E\right)e^{\alpha t} = \left(\frac{4P}{vA}\alpha\right)e^{\alpha t}$$

$$\frac{d}{dt}\left(Ee^{\alpha t}\right) = \frac{4P}{vA}\alpha e^{\alpha t}$$

Integrating an solving we get

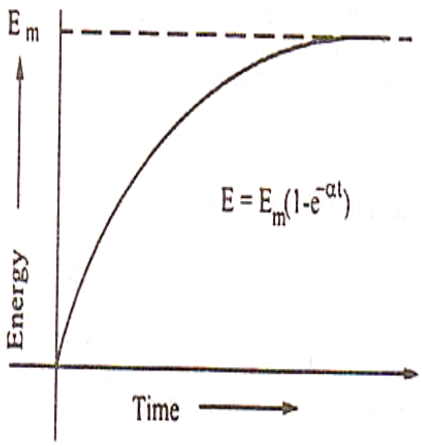
$$Ee^{\alpha t} = \frac{4P}{vA}.e^{\alpha t} + k \longrightarrow 8$$

Where k is the constant of integration

4.3.3.2 **Growth of Sound Energy**

Let us evaluate for growth

Initially during the growth the boundary conditions are at t= 0 E= 0



Therefore equation 8 becomes

$$0 = \frac{4P}{vA}.1 + k$$

$$k = -\frac{4P}{vA}.$$

Therefore substituting the value of k in equation 8 we can write

$$Ee^{\alpha t} = \frac{4P}{vA}.\alpha e^{\alpha t} - \frac{4P}{vA}$$

$$Ee^{\alpha t} = \frac{4P}{vA}\left(e^{\alpha t} - 1\right)$$

Since from equation 6 $E_m = \frac{4P}{vA}$, we can write

$$Ee^{\alpha t} = E_m\left(e^{\alpha t} - 1\right)$$

Dividing by $e^{\alpha t}$ throughout, we get

$$E = E_m\left(1 - \frac{1}{e^{\alpha t}}\right) \longrightarrow 9$$

Where E_m is the maximum sound energy.

This expression gives the growth of Sound energy density 'E' with time't'. The growth is along an exponential curve as shown in the figure.

This indicates that E increases until t = ∞

At t = ∞ ; E = E_{max}

4.3.3.3 DECAY OF SOUND ENERGY

Let us first evaluate k for decay.

Here the boundary conditions are at t = 0; E = E_m

Initially the sound increases from E to E_m and now it is going to decay from E_m. Therefore time is considered as'0' for E = E_m. At E = E_m, the sound energy from the source is cut off.

Therefore rate of emission of sound energy from the source = 0 i.e., P = 0

Therefore from equation 8 we can write

$$E_m e^0 = 0 + k$$

$$k = E_m$$

Therefore substituting the value of k for decay in equation 8 , we get

$$Ee^{\alpha t} = \frac{4P}{vA} e^{\alpha t} + E_m$$

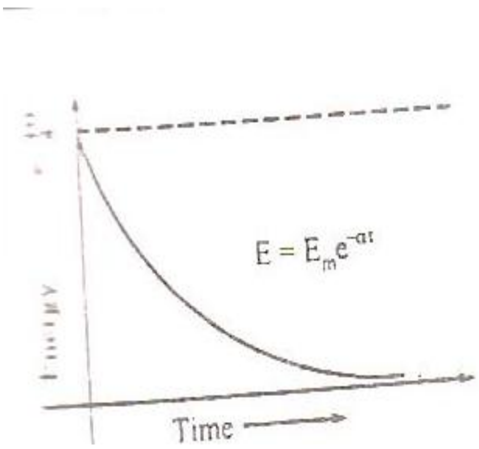
Since P = 0 Energy from the source is cutoff for decay of sound.

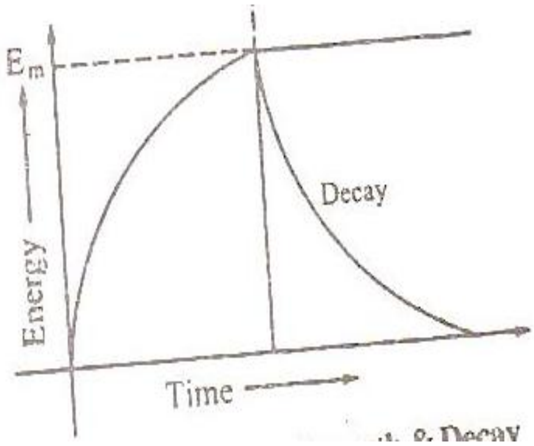
We can write

$$Ee^{\alpha t} = E_m$$

$$E = E_m e^{-\alpha t} \longrightarrow \quad 10$$

Equation 10 gives the decay of sound energy density with time't' even after the source is cut off. It is exponentially decreasing function from maximum energy (E_m) as shown. The growth and decay of sound energy together is represented in the figure.





4.3.3.4 PROOF OF RREVEREBARTION TIME (T)

According to Sabine, the reverberation time is defined as the time taken by a sound to fall to one millionth of its initial value, when the source of sound is cut off.

Time taken for E to be equal to $E = \frac{E_m}{10^6}$

Therefore condition is at t = T; $E = \frac{E_m}{10^6}$

Therefore equation 10 becomes $E = \frac{E_m}{10^6} = E_m e^{-\alpha t}$

$$10^{-6} = e^{-\alpha t}$$
$$10^{6} = e^{\alpha t}$$
$$\alpha t = \log_e 10_6$$
$$\alpha t = 6\log_e 10$$
$$\alpha t = 6 \times 2.3026 \log_{10} 10$$
$$\alpha t = 6 \times 2.3026 \times 1 \longrightarrow \quad 11$$

We know $\alpha = \frac{vA}{4V} \longrightarrow \quad 12$

Substituting equation 12 in 11, we get

$$\frac{vA}{4V} T = 6 \times 2.3026$$

$$T = \frac{4V \times 6 \times 2.3026}{vA}$$

We know the velocity of sound in air at room temperature v = 330m/s

$$\therefore T = \frac{4 \times 6 \times 2.3026}{330} \times \frac{V}{A}$$

$$T = \frac{0.167V}{A}$$

$$T = \frac{0.167V}{\sum as} \longrightarrow \quad 13$$

Where $\sum as = a_1 s_1 + a_2 s_2 + ...$.

Equation 13 represents the Reverberation time, which depends on the three factors viz.,

i. Volume of the hall(V)
ii. Surface area(S)
iii. Absorption coefficient (a) of the materials kept inside the hall.

Among these three factors volume is fixed. Therefore, the reverberation time can be optimized by either varying the surface area of the reflecting surfaces or the absorption coefficient of the materials used inside the hall.

4.4 ABSORPTION COEFFICIENT

We know that all the sound waves when pass through as open window passes through it. Thus, we can say that the open window behaves as a perfect absorber of sound and hence the absorption coefficient can be defined as the rate of sound energy absorbed by a certain area of the surface to that of an open window of same area.

Definition: The absorption coefficient of a surface is defined as the reciprocal of its area which absorbs the same amount of sound energy as absorbed by a unit area of an open window.

For example if 2m^2 of a carpet absorbs the same amount of sound energy as absorbed by 1 m^2 of an open window, then the absorption coefficient of the carpet is 1.2= 0.5. The absorption coefficient is measured in open window unit (O.W.U) or Sabines.

4.4.1 Average absorption coefficient

The average absorption coefficient is defined as the ratio between the total absorption in the hall to the total surface area of the hall.

$$\bar{a} = \frac{A}{S} = \frac{\sum as}{\sum s}$$

4.4.2 Measurement of sound absorption coefficient

Let us consider a sample for which the absorption coefficient (a_m) is to be measured. Initially without this material the reverberation time in a room is measured and let it be T_1. Now the given sample is kept inside the room and again the reverberation tme is measured and let it be T_2.

Then from Sabine's formula

For Case (1) i.e. without the sample

$$T_1 = \frac{0.167V}{\sum as} \longrightarrow 1$$

Where the total absorption = $\sum as = a_1s_1 + a_2s_2 + \ldots\ldots\ldots$.[for all the materials such as doors, windows etc]

For case 2 i.e. including the sample material

$$T_2 = \frac{0.167V}{\sum as + a_m s_m} \longrightarrow 2$$

a_m = absorption coefficient of the material to be found

S_m = surface area of the material

Therefore from equation 1 we have

$$\sum as = \frac{0.167}{T_1} \longrightarrow 3$$

$$\sum as + a_m s_m = \frac{0.167V}{T_2} \longrightarrow 4$$

Subtracting equation 3 from equation 4, we have

$$a_m s_m = 0.167V\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$a_m = \frac{0.167}{s_m}\left(\frac{T_1 - T_2}{T_1 T_2}\right)$$

Hence, by knowing the terms on the right hand side the absorption coefficient of the given sample can be determined.

4.4.3 FACTORS AFFECTING THE ACOUSTICS OF BUILDING

We know, when sound waves are produced in a hall, it reaches the observer directly as well as after reflections from walls, floors, ceilings, etc. Thus there is a possibility for causing interference between these waves, which in turn affects the originality of the sound produced.

The factors affecting the acoustics (sound) of buildings are as follows.

i. Unoptimised reverberation time
ii. Very low or very high loudness
iii. Improper focusing of sound to a particular area, which may cause interference
iv. Echoes or echelon effects produced inside the buildings
v. Resonance caused due to matching of sound waves.
vi. Unwanted sound from outside or inside the building, so called noise may also affect the acoustics of buildings.

4.4.3.1 OPTIMUM REVERBERATION TIME AND ITS REMEDY

We know Reverberation time is the time taken for the sound to fall to one millionth of its original sound intensity, when the source of sound is switched off.

This reverberation time plays a vital role in the auditorium, for clear audibility of sound. If the reverberation time is high then it produces, echoes in the hall and if the reverberation time is very low, the sound will not be clearly heard by the audience. Therefore, for clear audibility, we should maintain optimum reverberation.

The optimum reverberation time can be achieved by the following steps

1. By having the full capacity of audience in the auditorium.
2. By choosing absorbents like felt, fiber, board, glass etc inside the auditorium and even at the back of chairs.
3. Reverberation time can be optimized by providing windows and ventilators at the places wherever necessary and using curtains with folds for the windows.
4. The reverberation time can also be optimized by decorating the walls with beautiful pictures.

The optimum reverberation time will not be constant for all types of buildings; it varies from one building to another as follows.

i. For concert halls, the speech should have the optimum reverberation time of 0.5 seconds and music should have the optimum values of 1 or 2 seconds
ii. For auditorium, or theatres, the optimum reverberation time should be between 1.1 to 1.5 seconds for smaller area and between 1.5 to 3 seconds for larger area.

4.4.3.2 Loudness and its remedy:

We know loudness is the degree of sensation produced on the ear; it varies from observer to observer. But, it is found that for a single observer the loudness varies from one place to another in the same auditorium. This defect is caused due to the bad acoustical construction of buildings.

The loudness will be very low in some area and will be very high in some areas. It can be optimized by the following remedies.

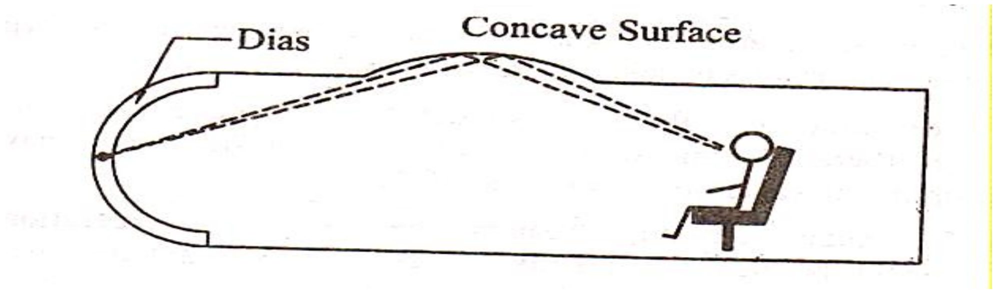
Remedies

i. Loudspeakers should be placed at the places where we have low loudness.
ii. The loudness can also be increased by making reflecting surfaces , wherever necessary
iii. Loudness can be increased by constructing low ceilings
iv. Absorbents are placed at the places where we have high loudness.

Thus, the loudness should be made even, all over the auditorium, so that the observer can hear the sound at a constant loudness at all the places.

4.4.3.3 FOCUSSING AND INTERFERENCE EFFECTS

In some places of a hall, the sound will not be heard properly and that place is said to be a dead space, which is due to presence of convex or concave surfaces in the hall as shown in the figure. Sometimes the sound waves will have interference pattern because of ceiling surfaces which will create maximum intensity of sound(due to constructive interference) in some places and minimum intensity of sound(due to destructive interference) at some places and hence causing uneven distribution of sound intensity in the hall and hence causing uneven distribution of sound intensity in the hall.



Remedies

- **i.** By avoiding curved surfaces (or) covering the curved surfaces by suitable absorbents, the focusing can be avoided.
- **ii.** By evenly polishing and decorating with absorbents the interference effects can be avoided.

4.4.3.4 ECHOES AND ECHELON EFFECT

In some halls, the walls of the halls will scatter the sound waves rather than reflecting it, thus way create nuisance effect due to echoes. The echoes are formed when the time interval between the direct and reflected sound waves are about $1/15^{th}$ of a second. This effect occurs due to the reason that the reflected sound waves reaches the observer later than the direct sound.

If there is a greater repetition of echoes of the original sound to the observer then the effect is called as Echelon effect.

Remedies

The echo can be avoided by lining the surfaces with suitable sound absorbing materials and by providing enough number of doors and windows.

4.4.3.5 RESONANCE

Resonance occurs when a new sound note of frequency matches with standard audio frequency. Sometimes, the window panel, sections of the wooden portion is thrown into vibrations to produce new sounds, which results in interference between original sound and created sound. This will create disturbance to the audience.

Remedies

- i. The resonance effect can be avoided by providing proper ventilation and by adjusting the reverberation time to the optimum level.
- ii. Nowadays the resonance is completely eliminated by air conditioning the halls.

4.4.3.6 NOISE

Noise is an unwanted sound produced due to heavy traffic outside the hall which leads to displeasing effect on the ear. There are three types of noises.

i. Air Borne noise
ii. Structure Born Noise
iii. Inside Noise

All these three noises pollute the area at which it has been produced and create harmful effects to the human beings. Fortunately human beings have the capability to reject the sound within certain limits with conscious efforts and to carry on his normal work. But sometimes the noises are strong which results in the following effects.

4.4.3.7 EFFECTS PRODUCED DUE TO NOISE POLLUTION

i. It produces mental fatigue and irritation.
ii. It diverts the concentration on work and hence reduces the efficiency of the work
iii. It sometimes affects the nervous system and lowers the restorative quality of sleep.
iv. Some strong noises leads to damage the eardrum and make the worker hearing impaired.
v. The noises which are produced regularly will even retard the normal growth of infants and young children.

a. AIR BORNE NOISE

The noise which reaches the hall through open windows, doors, and ventilations are called as air borne noise. This type of noise is produced both in rural areas [natural sound of wind and animals] and in urban areas] noise that arises from factories, aircrafts, automobile, trains. Flights etc

REMEDIES

i. By making the hall air conditioned, this noise may be eliminated
ii. By allotting proper places for doors and windows, this noise can be reduced.
iii. It can be further reduced by using double doors and windows with separate frames and by placing the absorbents in-between them

b. STRUCTURE BORNE NOISE

The noise that reaches the hall through the structures of the building is termed as Structure Borne noise. Those types of noises produced inside the building, which may be due to the machinery operation, movement of furniture's footsteps etc and these sounds will produce structural vibration giving rise to the Structure Borne Noise

REMEDIES

- **i.** By properly breaking the continuity of the interposing layers by some acoustical insulators this type of noise can be avoided.
- **ii.** By providing carpets, resilent, antivibration mounts etc., this type of noise can be reduced.

c. INSIDE NOISE

The noises that are produced inside the halls is known as inside noise. For example in some offices the sound produced by machinery, type writers ect produces this type of noise.

REMEDIES

- i. By placing the machineries and type writers over the absorbing materials or pads this type of noise can be redueced.
- ii. It can be reduced by covering the floors with carpet.
- iii. By fitting the engine on the floor with a layer of wood or felt between them this type of noise can be avoided.

4.4.3.4 FACTORS TO BE FOLLOWED FOR GOOD ACOUSTICS OF BUILDING

To have a clear audibility of sound in auditorium, the following factors are to be followed.

- i. The reverberation time should have an optimum level
- ii. The sound must be evenly distributed to each and every part of the building.
- iii. There should not be any focusing of sound to any particular area.
- iv. Each and every syllable of sound must be heard clearly and distinctly, without any interference.
- v. There should not be any echoes, echelon effects and resonance inside the buildings
- vi. The buildings should be made as sound proof building, so that external noises may be avoided.

vii. Generally to say the total quality of sound should be maintained all over the building, to all the audience.

4.5 Ultrasonic

4.5.1 Properties of Ultrasonic waves

The human ear is sensitive to sound waves in the frequency range from 20-20,000 Hz. This range is called Audible range. Sound waves of frequency more than 20,000 Hz are called Ultrasonics. These frequencies are beyond the audible limit.

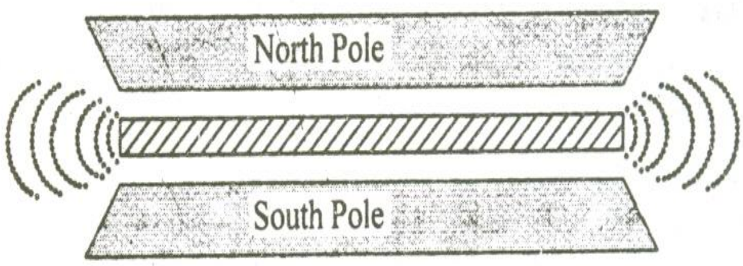
These waves also travel with the speed of sound (330m/s)

Their wavelengths are small.

4.5.2Production of Ultrasonic waves

4.5.2.1 Magnetostriction Method

Principle: When a rod of ferromagnetic material like nickel is magnetized longitudinally, it undergoes a very small change in length. This is called Magnetostriction effect.

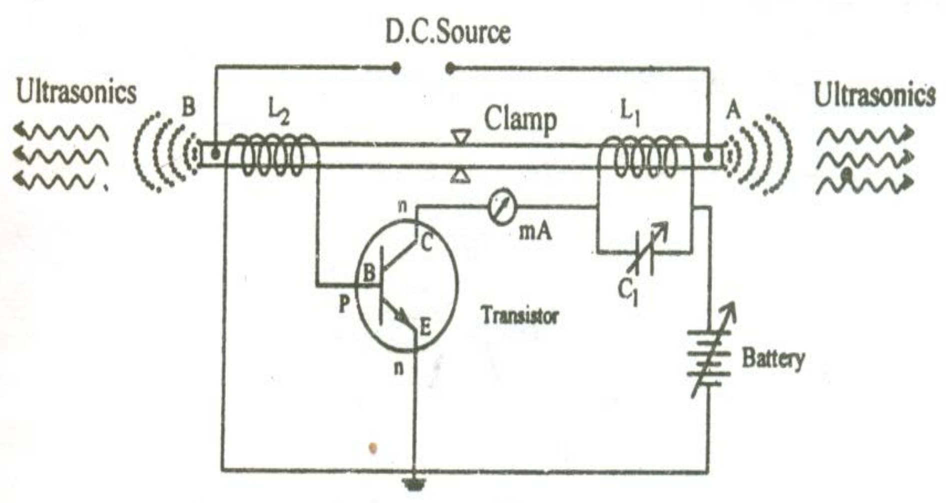


Figure

Construction:

The circuit diagram of magnetostriction ultrasonic generator is as shown in the figure 1.3.2. A short permanently magnetized nickel rod is clamped in the middle between two knife-edges. A coil L_1 is wound on the right hand portion of the rod. C is a variable capacitor. L_1 and C_1 form the resonant circuit of the collector-tuned oscillator. Coil

L_2 wound on the LHS of the rod is connected in the base circuit. The coil L_2 is used as a feed- back loop.



Figure

Working:

When the battery is switched on, the resonant circuit L_1 C_1 sets up an alternating current of frequency

$$F = \frac{I}{2\pi\sqrt{L_1C_1}}$$

This current flowing round the coil L_1 produces an alternating magnetic field of frequency f along the length of the nickel rod. The rod starts vibrating due to magnetostrictive effect. The vibrations of the rod create ultrasonic waves.

The longitudinal expansion and contraction of the rod produces an E.M.F in the coil L_2. This e.m.f is applied to the base of the transistor. Hence the amplitude of high frequency of high oscillations in coil L_1 is increased due to positive feedback.

The developed alternating current frequency can be tuned with the natural frequency of the rod by adjusting the capacitor.

Condition for Resonance:

Frequency of the oscillator circuit = Frequency of the vibrating rod

$$F = \frac{I}{2\pi\sqrt{L_1C_1}} = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

Where 'l' is the length of the rod

'E' is the Young's modulus of the rod

'ρ' is the density of the material of the rod.

The resonance condition is indicated by the rise in the collector current shown in the milliammeter.

Advantages

- Magnetostriction Oscillators are mechanically rugged.
- The construction cost is low.
- They are capable of producing large acoustical power with fairly good efficiency.

Limitations

- It can produce frequencies up to 3MHz only.
- The frequency of oscillation depends upon the temperature.
- Breadth of the resonance curve is large. It is due to vibrations of elastic constants of ferromagnetic material with the degree of magnetization. So we cannot get a constant single frequency.

4.5.2.2 Piezo Electric Crystals

The crystals which produce piezo-electric effect and converse Piezo-electric effect are termed as Piezo-electric crystal.

Examples: Quartz, Tourmaline, Rochelle Salts etc.

At typical example for a piezo-electric crystal (Quartz) is as shown in the figure 1.4.1. It has an hexagonal shape with pyramids attached at both ends. It consists of 3 axes . viz.,

(i) Optic Z axis, which joins the edges of the pyramid

(ii) Electrical axis(X axis), which joins the corners of the hexagon and

(iii) Mechanical axis, which joins the center or sides of the hexagon as shown

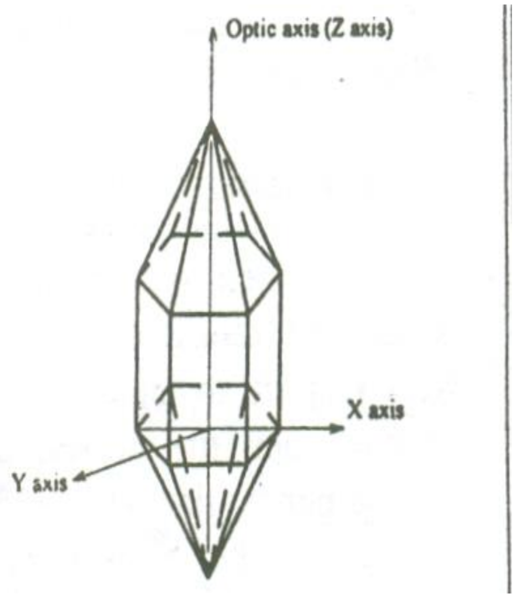
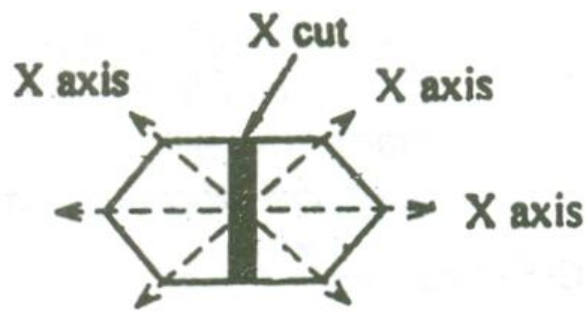


Figure 1.4.1



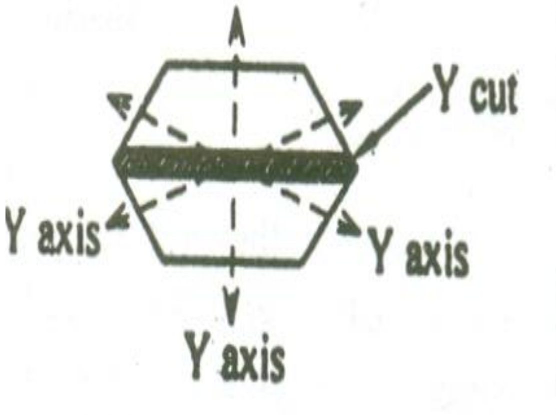


Figure 1.4.2 **figure 1.4.3**

X-cut and Y cut crystals

X - Cut crystal :

When the crystal is cut perpendicular to the X- axis, as shown in the figure 1.4.2, then it is called X – crystal.

Generally X- cut crystals are used to produce longitudinal ultrasonic waves.

Y-cut Crystal:

When the crystal is cut perpendicular to the Y –axis, as shown in the figure 1.4.3, then it is called Y –cut crystal.

Generally, Y –cut crystals produces transverse ultrasonic waves.

Piezoelectric Effect:

Definition: When a mechanical stress is applied to the mechanical axis with respect to optical axis, a potential difference is developed across the electrical axis with respect to optic axis

Inverse Piezoelectric Effect:

Definition: When an alternating electric field is applied to electrical axis with respect to optical axis, expansion or contraction takes place in the mechanical axis with respect to optical axis.

4.5.2.3 Production of Ultrasonic waves - Piezo-Electric Effect

Principle:

This is based on the ***Inverse piezoelectric effect.*** When a quartz crystal is subjected to an alternating potential difference along the electric axis, the crystal is set into elastic vibrations along its mechanical axis. If the frequency of electric oscillations coincides with the natural frequency of the crystal, the vibrations will be of large amplitude. If the frequency of the electric field is in the ultrasonic frequency range, the crystal produces ultrasonic waves.

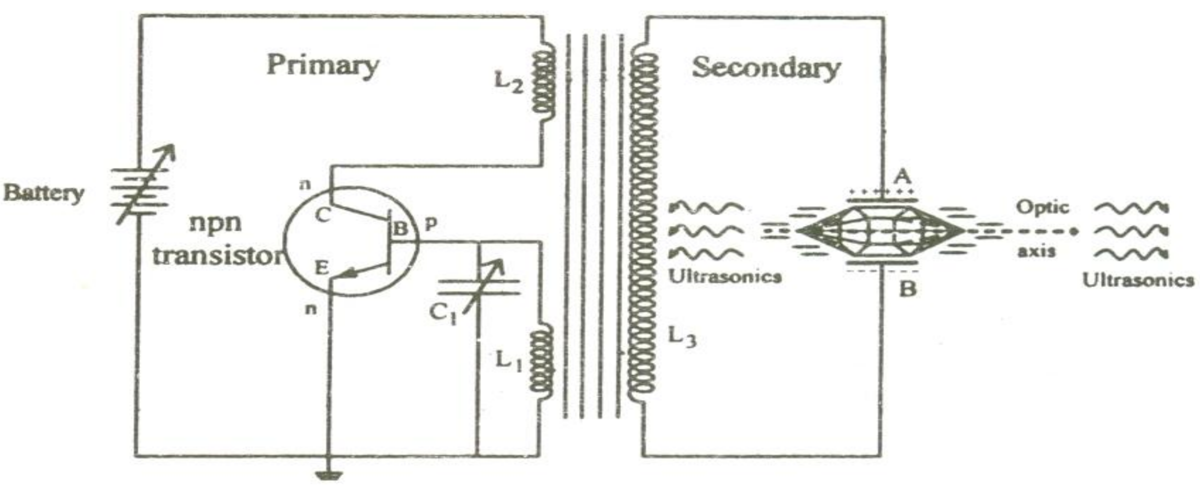


Figure Piezo-Electric Oscillators

Construction:

The circuit diagram is shown in the figure 1.5 It is base tuned oscillator circuit. A slice of Quartz crystal is placed between the metal plates A and B so as to form a parallel plate capacitor with the crystal as the dielectric. This is coupled to the electronic oscillator through the primary coil L_3 of the transformer.

Coils L_2 and L_1 of oscillator circuit are taken for the primary of the transformer. The collector coil L_2 is inductively coupled to base coil L_1. The coil L_1 and variable capacitor C form the tank circuit of the oscillator.

Working:

When the battery is switched on, the oscillator produces high frequency oscillations. An oscillatory e.m.f is induced in the coil L_3 due to ***transformer*** action. So the crystal is now under high frequency alternating voltage.

The capacitance of C_1 is varied so that the frequency of oscillations produced is in resonance with the natural frequency of the crystal. Now the crystal vibrates with larger amplitude due to resonance. Thus high power ultrasonic waves are produced.

Condition for Resonance:

Frequency of the oscillator circuit = Frequency of the vibrating crystal

$$F = \frac{I}{2\pi\sqrt{L_1C_1}} = \frac{P}{2l}\sqrt{\frac{E}{\rho}}$$

Where 'l' is the length of the crystal

'E' is the Young's modulus of the rod

' 'ρ' is the density of the material of the rod

'P' = 1, 2, 3 …etc for fundamental, first overtone, second overtone etc respectively

Advantages:

1. Ultrasonic frequencies as high as 500 MHz can be generated.
2. The output power is very high. It is not affected by temperature humidity.
3. It is more efficient than the Magnetostriction oscillator.
4. The breadth of the resonance curve is very small. So we can get a stable and constant frequency of ultrasonic waves.

Disadvantages:

1. The cost of the quartz crystal is very high.
2. Cutting and shaping the crystal is quite complex.

4.6 Sound Navigation and Ranging (SONAR)

Principle:

It is based on the principle of Echo – Sounding. When the Ultrasonic waves are transmitted through water, it is reflected by the objects in the water and will produce an echo signal. The change in frequency of the echo signal, due to Doppler Effect helps us in determining the velocity and the direction of the object.

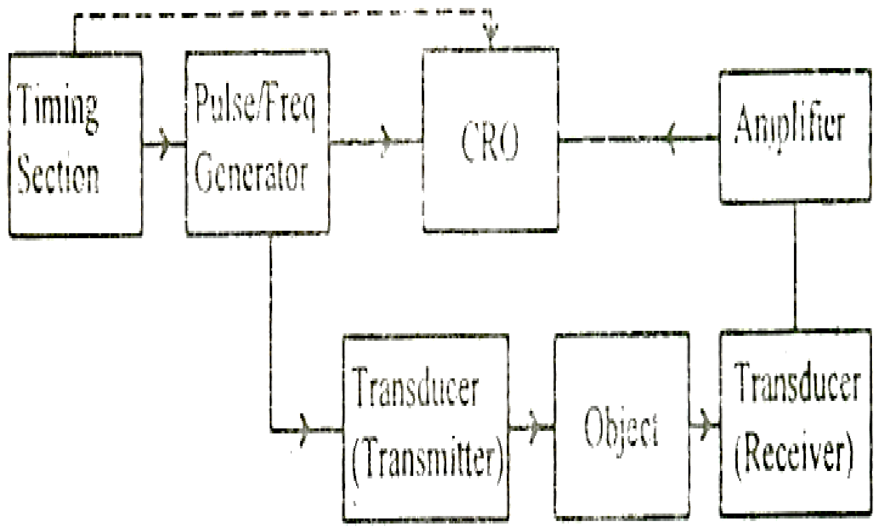


Figure 1.6.1

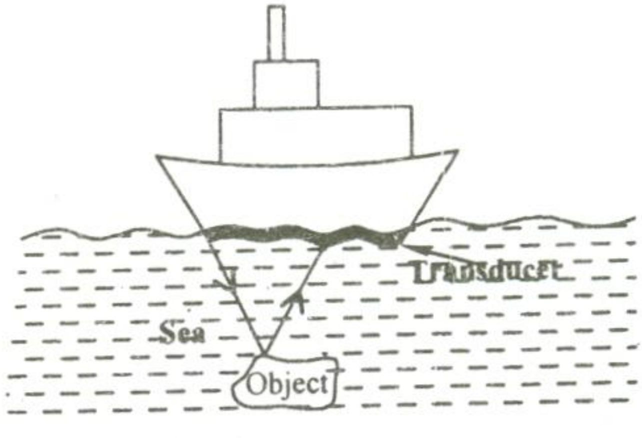
Description:

It consists of timing section which triggers the electric pulse from the pulse generator. This pulse generator is connected to the transducer so that ultrasonics can be produced. The transducer is further connected with the CRO for display. The timing section is also connected to the CRO display for reference of the timing at which the pulse is transmitted as shown in the block diagram (Figure 1.6.1)

Working:

The transducer is mounted on the ship's hull without any air gap between them as shown. The timing at which the pulse generated is recorded at the CRO for reference and this electrical pulse triggers the transducer which is kept in the hull of the ship to produce ultrasonic waves due to the principle of inverse piezo-electric effect.

These ultrasonic waves are transmitted through the water in sea. On stricking the object the ultrasonic waves (*echo pulses*) are reflected in all directions as shown in the figure 1.6.2



Figure

Cavitation:

Definition: The Ultrasonic sound waves that propagate into the liquid media result in alternating *high-pressure (compression)* and *low-pressure (rarefaction)* cycles, with rates depending on the frequency.

During the *low-pressure cycle, high-intensity ultrasonic waves create small vacuum bubbles* or voids in the liquid. When the bubbles attain a volume at which they can no longer absorb energy, they *collapse violently during a high-pressure* cycle. This phenomenon is termed cavitation.

During the implosion very high temperatures (approx. 5,000K) and pressures (approx. 2,000atm) are reached locally. The implosion of the cavitation bubble also results in liquid jets of up to 280m/s velocity.

Acoustic Grating

The ultrasonic waves generated with the help of a quartz crystal inside the liquid in a container sets up standing wave pattern consisting of nodes and anti-nodes. The *nodes are transparent and anti-nodes are opaque* to the incident light.

In effect the *nodes and anti-nodes acts like grating* (a setup of large number of slits of equal distance) similar to that of rulings in diffraction grating. It is called as acoustic grating or aqua grating. At nodes the density of the liquid is maximum and at antinodes density is minimum. This arrangement is very much similar to the diffraction grating and is called acoustic grating.

Hence, by using the condition for diffraction, we can find the wavelength of ultrasound and thereby the velocity of sound in the liquid medium.

Acoustic Grating

When ultrasonic waves are generated in a liquid kept in rectangular vessel, the wave can be reflected from the walls of the vessel. The direct and reflected waves get superimposed, which causes a standing wave to be formed. *The density of the liquid at the node will be more than the density at an antinode.* Under these conditions, if a beam of light is passed through the liquid at right angles to the wave the liquid acts as a diffraction grating. Such a grating is known as an *acoustical grating*.

Here, the *antinode acts as the transmitting slit* and the node acts as the opaque part...thus resembling a normal ruled diffraction grating. This is obvious because the nodes have points of minimum density and hence allow more amount of light to pass through them than those at antinodes. Thus, the nodes act like slits.

Diffraction Grating:

A Diffraction grating is an extremely useful device. It consists of large number of narrow slits side by side. The slits are separated by opaque surfaces. When a wavefront is incident on the grating surface, light is transmitted through the slits and obstructed by the opaque spaces. Such a grating is called transmission grating.

4.7 Determination of Ultrasonic Velocity in Liquid

(Acoustical Grating Method)

Principle:

When ultrasonic waves travel through a transparent liquid, due to alternate compression and rarefaction, longitudinal stationery waves are produced. If monochromatic light is passed through the liquid perpendicular to these waves, the liquid behaves as diffraction grating. Such a grating is known as Acoustic Grating. Here the lines of compression and rarefaction act as transparent light waves. It is used to find wavelength (λ) and velocity (v) of ultrasonic waves in the liquid.

Construction:

It consists of a glass tank, filled with the liquid. A piezo-electric (Quartz) is fixed at the bottom of the glass tank and is connected with piezo-electric oscillatory circuit as shown in the figure 1.7

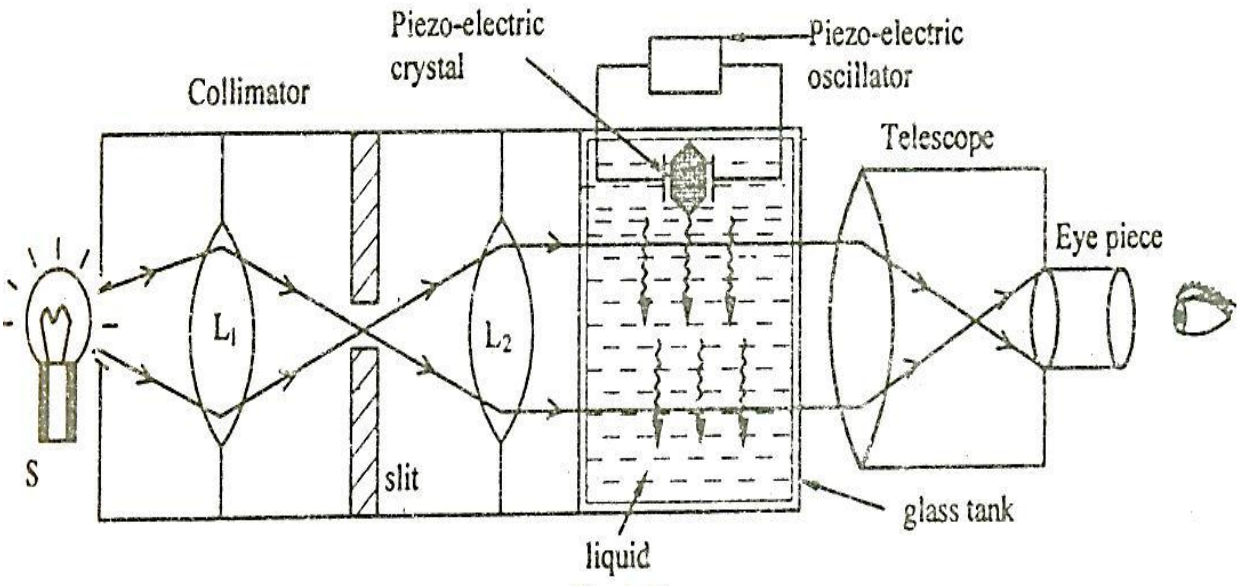


Figure 1.7.1

An incandescent lamp is used as a monochromatic source (S) and a telescope arrangement is used to view the diffraction pattern. A collimator consisting of two lenses L_1 and L_2 is used to focus the light effectively in the glass tank.

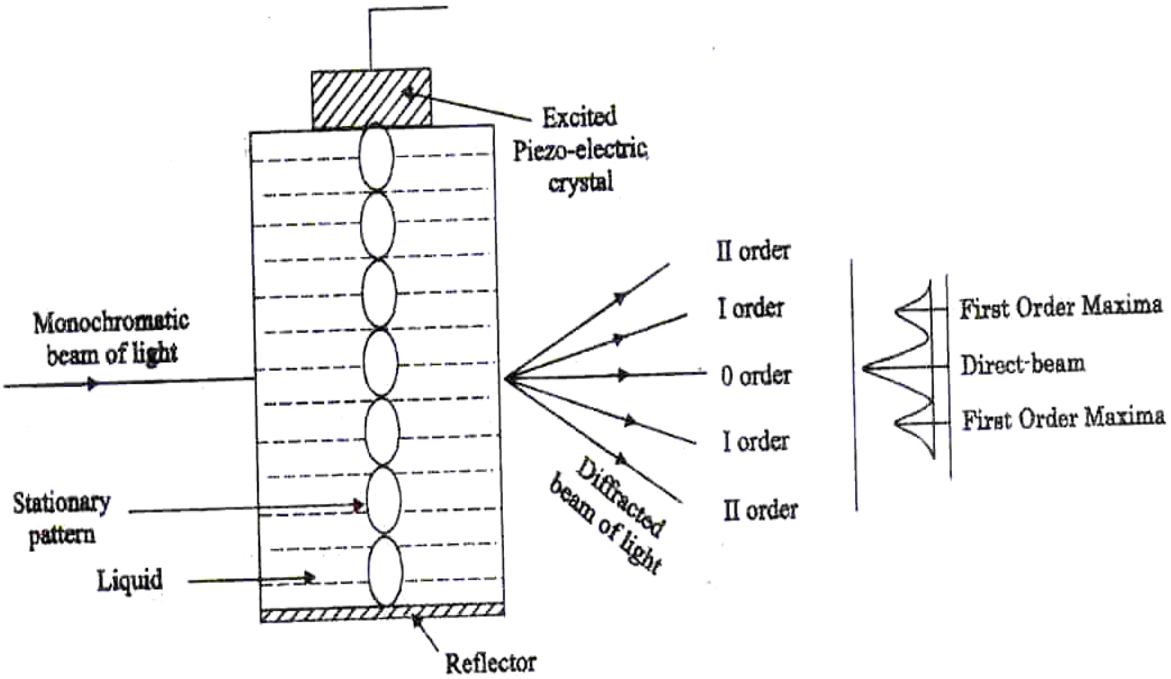


Figure 1.7.2

Working

(i) When the piezo-electric crystal is kept at rest:

Initially the piezo-electric crystal is kept at rest and the monochromatic at light is switched ON. When the light is focused in the glass tank filled with the liquid, a single image, a vertical peak is observed in telescope. i.e., there is no diffraction.

(ii) When the piezo-electric crystal is set into vibrations:

Now the crystal is put into vibrations using piezo-electric oscillatory circuit. At Resonance, Ultrasonic waves are produced and are passed through the liquid. These Ultrasonic waves are reflected by the walls of the glass tank and form a stationery wave pattern with nodes and antinodes in the liquid. At nodes the density of the liquid becomes more and at antinodes the density of the liquid becomes less. Thus, the liquid behaves as a diffracting element called *acoustical grating element.*

Now when the monochromatic light is passed the light gets diffracted and a diffraction pattern consisting of central maxima and principle maxima on either side is viewed through the telescope as shown in figure 1.7.2 as well as in 1.7.3.

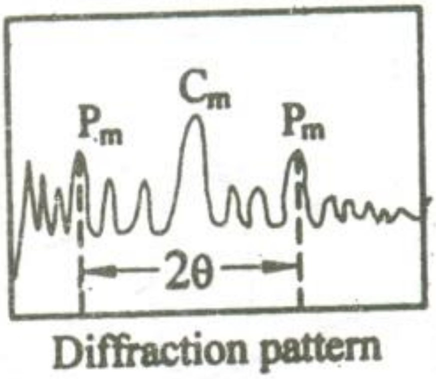


Figure 1.7.3

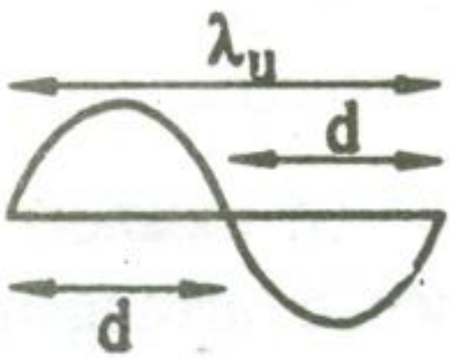


Figure1.7.4

Calculation of Ultrasonic Velocity

The velocity of Ultrasonic waves can be determined using the condition.

$$2d\sin\theta = n\lambda \longrightarrow \quad (1)$$

Where, d is the distance between successive node or antinodes.

θ is the angle of diffraction

n is the order of the spectrum

λ_L is the wavelength of the monochromatic source of the light.

If $\lambda_u = 2d$ ⟶ (2)

Then, equation (1) becomes,

$$\lambda_u \sin\theta = n\lambda$$

Wavelength of Ultrasonic = $\lambda_u = \dfrac{n\lambda}{\sin\theta}$ ⟶ (3)

We know, Ultrasonic Velocity = Frequency of Ultrasonic $\times$ Wavelength of ultrasonic

Velocity of Ultrasonic $v = \lambda_u \times \nu_u$ ⟶ (4)

Substituting equation (3) in (4) , we get

Velocity of Ultrasonic $v = \dfrac{\nu_u n\lambda}{\sin\theta}$

Thus, this method is useful in measuring the wavelength and velocity of ultrasonic waves in liquids, and gases at various temperatures.

4.8 INDUSTRIAL APPLICATIONS

4.8.1 Application of ultrasonic waves

Ultrasonic waves find application in two major fields:

a) Engineering filed.
b) Medical field

Applications of ultrasonic waves in engineering and industry

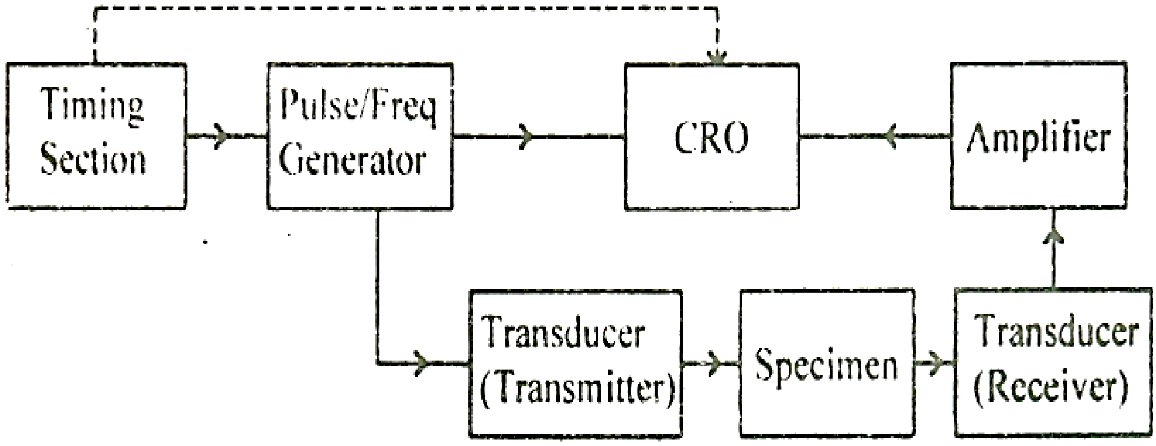
Ultrasonic waves find wide applications in engineering and industry as follows.

1. Non- destructive testing(detection of flaws in metals)

2. Ultrasonic drilling
3. Ultrasonic welding
4. Ultrasonic drilling
5. Ultrasonic soldering
6. Ultrasonic cutting and machinery
7. Ultrasonic cleaning
8. Sonar

4.8.1.2 Ultrasonic Non- destructive Testing

Principle: *The basic principle behind the ultrasonic inspection is the transmission of the Ultrasound with the medium and the reflection or scattering at any surface or internal discontinuity in the medium due to the change in the acoustic impedance.* The Discontinuity means the existence of the flaw or defect or cracks or hole in the material. *The reflected or scattered sound waves are received and amplified and hence, the defects in the specimen are suitably characterized.*



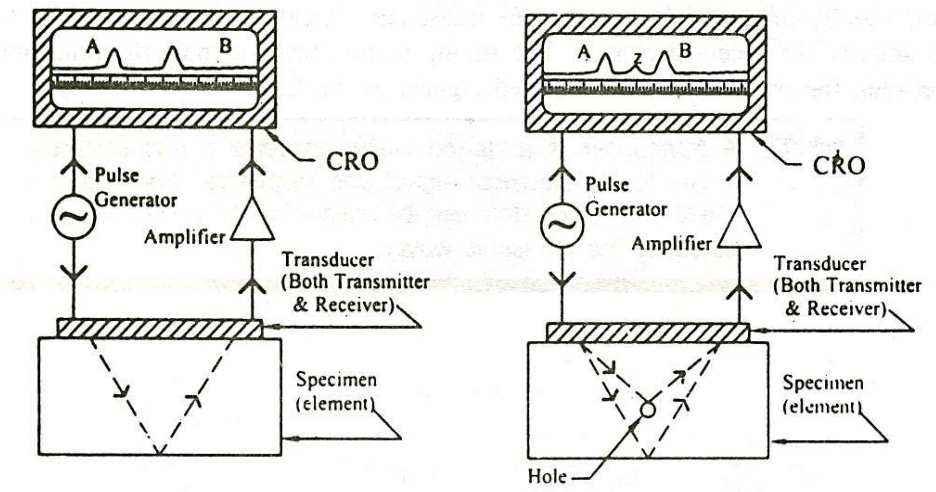
1.8.1 Block diagram of the Ultrasonic Flaw detector

Principle:

Whenever there is a change in the medium, then the Ultrasonic waves will be reflected. This is the principle used in Ultrasonic flaw detector. Thus, from the intensity of the reflected echoes, the flaws are detected without destroying the material and hence this method is known as a Non –Destructive method.

Working:

a. The pulse generator generates high frequency waves and is applied to the Piezo-electric transducer and the same is recorded in the CRO.
b. The piezo-electric crystals are resonated to produce Ultrasonic waves.
c. These Ultrasonic waves are transmitted through the given specimen.
d. These waves travel through the specimen and is reflected back by the other end.
e. The reflected Ultrasonic are received by the transducer and is converted into electric signals. These reflected signals are amplified and is recorded in the CRO.
f. If the reflected pulse is same as that of the transmitted pulse, then it indicates that there is no defect in the specimen.
g. On the other hand, if there is any defect on the specimen like a small hole or pores, then the Ultrasonic will be reflected by the holes (i.e.) defects due to change in the medium.
h. From the time delay between the transmitted and received pulses, the position of the hole can be found.
i. From the height of the pulse received the depth of the hole can also be determined.



4.9 ULTRASONIC SCANNING MMETHODS- A, B AND C SCAN DISPLAYS

In the Ultrasonic scanning methods, the principle, construction and working is the same as that of the Ultrasonic flaw detector. Here, it is based on the position of the transducer and the output displayed in the CRO screen, we can classify the scanning methods into three types

a. **A-scan**
b. **B-scan**
c. **T-M – scan or C-scan**

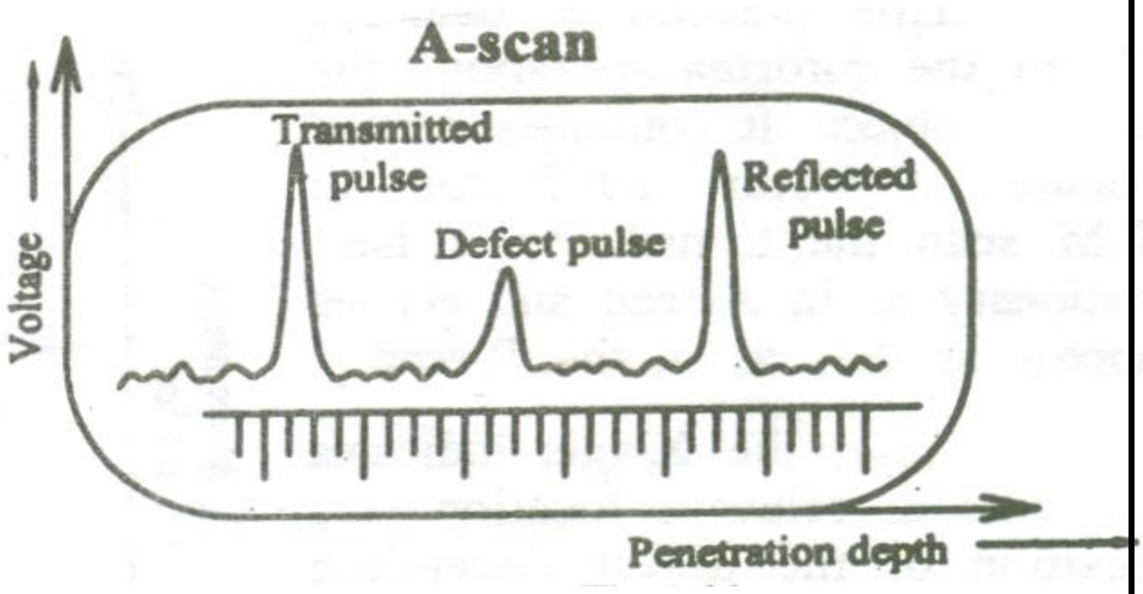
All these three modes of scanning are obtained with respect to the pulses of Ultrasound transmitted into and received from the specimen. The three modes are explained below.

a. A-Scan or Amplitude mode display

Amplitude mode display gives only *one-dimensional* information about the given specimen. In this, a single transducer is used to transmit and receive the pulses from the specimen.

The received or the reflected echo signals from the specimen is given to the Y – Plate and time base is connected to the X- Plate of the CRO, so that they are displayed as vertical spikes along horizontal base line as shown in the figure 1.10.1

The height of the vertical spikes corresponds to the strength of the echo from the specimen. The position of the vertical spike from left to right along the X-axis corresponds to the depth of penetration i.e., it gives the total time taken by the Ultrasonic sound to travel from transmitter to the specimen and from the specimen to the receiver.



Figure

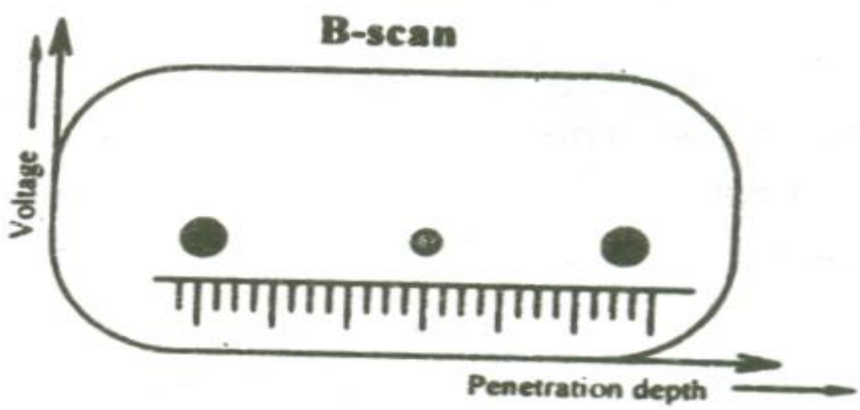
Thus by passing Ultrasonic waves of known velocity and by noting the time delay, we can find the distance at which the defect or flaws are present, by using the formula

Distance = Velocity × time

In ultrasonic flaw detector, A-scan method is used to detect the position and size of the flaws.

b. B-Scan or Brightness Mode Scan

B-Scan or Brightness mode display gives a two dimensional image. The principle of the B- Scan is same as that of A-Scan except with a small difference. Here in the B-Scan the transducer can be moved rather than keeping in a fixed position. As a result each echo's are displayed as dots on the screen as shown in the figure 1.10.2

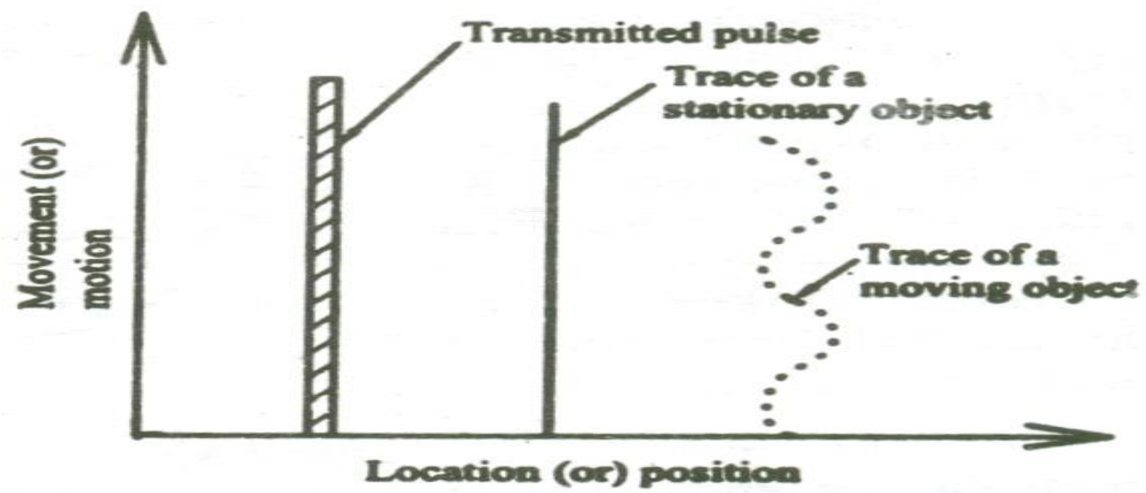


Figure

c. T.M Scan or Time – Motion Mode or C-Scan display

This method is used to obtain the information about the moving object.

This combines the features of both A-scan as well as B Scan. In this the transducer is held stationery as in A-scan and echoes appear as dots in the B-scan.



Figure

Here, the X- axis indicates the dots at the relevant location and the Y –axis indicates the movement of the object. Therefore when the object moves, the dot also moves at a low speed. Thus an object with the oscillatory movement will appear as a trace as shown in the figure 1.10.3.

4.10 Sonogram- Recording of movement of Heart

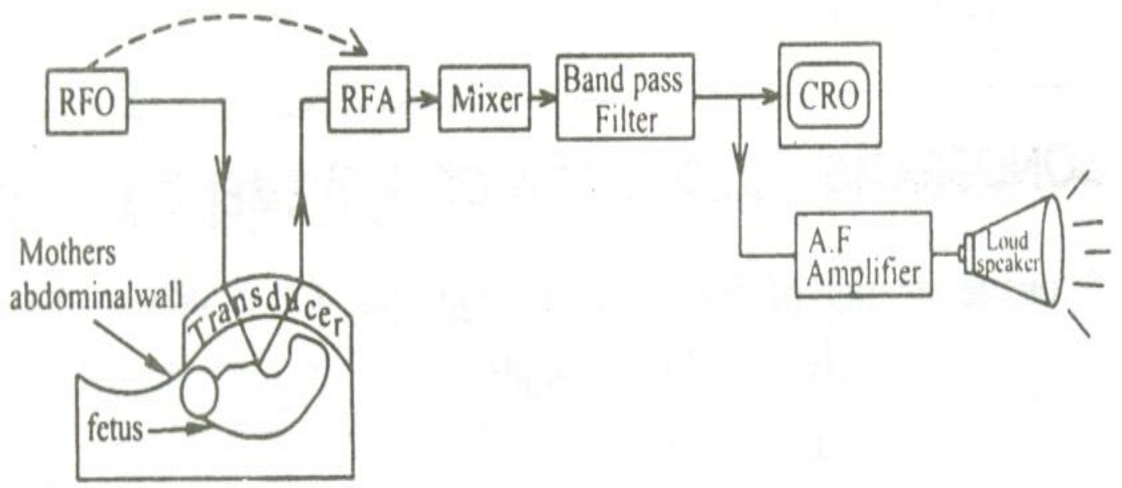
4.10.1 Fetal Heart Movement

Principle:

It works under the principle of Doppler Effect i.e., there is an apparent change in the frequency between the incident sound waves on the fetus and the reflected sound waves from the fetus.

Description:

It consists of a Radio Frequency Oscillator (RFO), for producing 2 MHz of frequency and RFA (Radio Frequency Amplifier) to amplify the receiver signals as shown in the figure



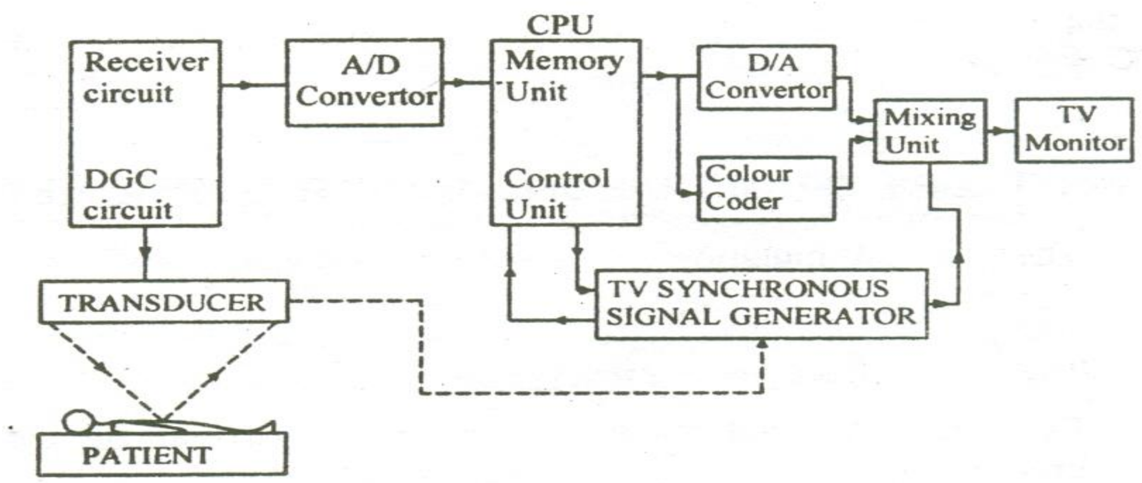
Figure

Working:

The transducer is fixed over the mother's abdominal wall, with the help of a gel or oil. RFO is switched on to drive the pulses and hence the transducer produces Ultrasonic waves of 2 MHz. These Ultrasonic waves are made to be incident on the fetus.

The reflected Ultrasonic waves from the fetus are received by the transducer and are amplified by RFA. Both the incident and the received signals are mixed by the mixer and is filtered to distinguish the various types of sound and finally the Doppler shift or change in frequency is measured. The movement of the heart can be viewed visually by CRO or can be heard by the Loud Speaker, after necessary amplification by AF.

4.10.2 Ultrasonic Imaging System



Principle of Working

- During the scanning of the body surface by Ultrasonic transducer, the Ultrasonic waves are transmitted into the patient's body.
- The echoes from the body are collected by the receiver circuit.
- Since some echoes come from the depth, they are weak; therefore, proper depth gain compensation is given by DGC circuit.
- Then these signals are converted into digital signals by an analog to digital converter and are stored in the memory of the Control Processing Unit (CPU) of a computer.
- Meanwhile, the control unit in the CPU receives the signals of transducer position and TV synchronous pulses. These signals generates X plate and Y plate address information's for the T.V monitor and is also stored in the memory of the CPU.
- The stored signals are processed and colour coded and is given to the digital to analog (D/A converter), which converts the digital signal into analog signal.
- Finally the mixing circuit mixes the analog signals and TV synchronous signals properly. The mixed signals are finally fed to the video section of the television monitor as shown in the figure 1.12.
- The TV monitor produces the coloured Ultrasonic image of the internal part of the Body

UNIT IV ACOUSTICS AND ULTRASONICS

Two mark Questions and answers.

1. How are sound waves classified?

   Sound waves are classified into three categories.

   a. Infrasonic (below 20 Hz)

   b. Audible Sound (between 20 Hz and 20,000 Hz)

   c. Ultrasound (above 20,000 Hz)

2. Name the methods by which Ultrasonic waves could be generated.

   a. Mechanical generators.

   b. Magnetostrictiion Generators or Oscillator

   c. Piezoelectric Generator or Oscillator

3. What is the principle behind the Magnetostrictiion Oscillator? Or what is meant by Magnetostriction effect.

Magnetostriction effect is the principle of producing Ultrasonic waves by using Magnetostriction Oscillator.

When an alternating magnetic filed is applied to a rod of ferromagnetic rod such as Nickel, Iron or Cobalt, then the rod is thrown to ***longitudinal*** vibrations. When the frequency of the vibration rod is equal to the natural frequency of the vibration, ***Resonance*** occurs. This produces Ultrasonic waves.

4. What is meant by Sonar?

   SONAR is a device, which stands for Sound Navigation and Ranging. The principle of Sonar is based on the echo surrounding technique of Ultrasonics. It is the acoustical technique for locating the objects like submarine or icebergs etc by transmitting a high frequency sound pulse and receiving it after reflection from that object.

5. What is piezoelectric effect? Define the converse piezoelectric effect also.

   When pressure or mechanical force is applied along mechanical axis with respect to the Optic axis then equal and opposite charges are produced along the electrical axis with respect to the Optic axis. This effect is called **Piezo-electric effect.**

   When potential difference or e.m.f is applied along the electrical axis with respect to the Optic axis of the piezoelectric crystal, the crystal starts vibrating along the optic axis mechanical axis of the crystal with respect to the Optic axis. This effect is called **Converse or Inverse Piezo- electric effect.**

6. What is the principle of the piezoelectric Oscillator?

The principle of the Piezo –Electric oscillator is **Converse Piezo-electric effect or Inverse Piezo- electric effect**. When potential difference or e.m.f is applied along the electrical axis with respect to the Optic axis of the piezoelectric crystal, the crystal starts vibrating along the optic axis mechanical axis of the crystal with respect to the Optic axis. This effect is called **Converse or Inverse Piezo- electric effect.**

7. Mention the applications of Ultrasonics.
    a. Ultrasonic are used in cutting, drilling welding, soldering etc.
    b. They are used to increase the sensitivity of the colour in photographs by dispersion of the dye in the emulsion.
    c. They are used to remove air bubbles in the liquid metals and convert them into fused metals.
    d. Low frequency ultrasonic waves are used in sorting paper fibers from the paper pulp.
8. What is meant by Cavitation?

    Cavitation is the process of creation and collapse of the bubbles, due to the principle of negative local pressure created inside the bubble.
9. What are the medical applications of the Ultrasonics in industries?
    a. **Diagnostic application**: Ultrasonic waves are used for detecting tumours and other defects in Human body.
    b. **Surgical Application**: Ultrasonic waves are used to remove the kidney stones and brain tumours without the loss of blood.
    c. **Disease treatment**: Ultrasonic waves are used to treat diseases like neuralgic and rheumatic pains etc.
10. What is the principle of finding the velocity of ultrasonic using acoustical grating?

    PRINCIPLE: When the Ultrasonic waves are passed through a liquid like kerosene contained in a tank, due to variation in pressure, the liquid acts as acoustical grating. Now when monochromatic source of light is passed through the acoustical grating, it produces orders of spectrum due to diffraction. Using diffraction condition we can find the velocity of Ultrasonic i.e. $v = \gamma_u \lambda_u$ where γ_u is the frequency of the Ultrasonic waves and λ_u is the wavelength of the Ultrasonic waves.

11 What are the factors affecting the acoustic quality of a building

12. Define absorption coefficient of the material

13. Define reverberation time of an auditorium

14. What is loudness? Give the relation between the loudness and intensity of sound or State Weber Fechner Law.

15. If the reverberation time is lower than the critical value, how will it affect the acoustical quality of a building?

Ans : when the reverberation time is lower than the critical value, sound becomes inaudible by the observer and the sound is said to be dead and if the reverberation time is too large,e choes are produced. Therefore the reverberation time should have optimum value.

16. Mention any four sound absorbing materials.

17. Define sound intensity level and write its unit.

ANNA UNIVERSITY Part B QUESTIONS

18. Describe piezo electric method of producing ultrasonic waves.

19. Explain how ultrasonic waves can be produced by using piezo electric crystal and write any four applications of ultrasonics.

20. Discuss the applications of ultrasonics in Sonar.

21Draw the block diagram of ultrasonic flaw detector and explain the function of each one of its components.

22What are ultrasonic waves? Explain with neat circuit diagram the generation of ultrasonic waves using piezoelectric oscillator.

23Discuss the application of ultrasonics in measurement of velocity of blood flow.

24Draw the block diagram of ultrasonic flaw detector. Explain the three different scan displays used for data presentation.

25What are magnetostriction and piezoelectric effects? Write down the complete experimental procedure with the neat circuit diagram of producing ultrasonic waves by magnetostriction effect

26. Explain the determination of velocity of ultrasonics using an acoustical grating.

27. Derive an expression for the reverberation period of an auditorium and explain how this can be used for determining the absorbing power of surface involved.

28. Write in detail about the factors affecting architectural acoustics and their remedies

29. What is reverberation time? Using Sabines formulas explain how the sound absorption coefficient of a material is determined?

30. Derive the expressions for growth and decay of sound energy.