UNIT – IV

Phy

Ultrasonics

Audiable waves are that confined to the frequency range from 20 Hz to 20 KHz. such waves are known as sonics.

Eg: The waves produced by vibrating bodies such as stretched strings.

Infrasonics:—

Infrasonic waves are that range of sound wave frequency with in which the human ear is not capable of receiving sound energy. usually, infrasonic waves have their frequency less than the lower limit of audible range (ie, below 20 Hz)

Eg: These waves are produced by large sources such as earthquakes.

Ultrasonics:—

The sound waves in which the frequencies are above the limits of human audibility ie, frequencies greater than 20 KHz are reffered to ultrasonics.

Because of high frequency, we can't hear these waves. Bats and dogs are able to hear such waves.

The wave length ultrasonic waves are very small as compared to audiable sound. So, most of the applications of ultrasonic waves have been possible on account of their small wave lengths.

These waves also known as supersonic waves. Sound waves of frequency higher than 10^8 Hz are known as hypersonic waves.

Properties:—

1. Ultrasonic wave are highly energetic, high frequency in audible sound waves.
2. They show negligible diffraction due to their smaller wavelength. Hence, they can be transmitted over long distances without any loss of energy.
3. Intense ultrasonic radiation has a disruptive effect in liquids by causing bubbles to be formed
4. Ultrasonic wave requires a material medium for its propagation.
5. Their velocity of propagation is directly proportional to its frequency.
6. During the propagation of ultrasonic wave they are reflected, scattered, and diffracted.
7. Ultrasonic waves set up standing waves in liquid baths and in turn produces an acoustical grating.

Production of ultrasonics.

Ultrasonic waves are usually produced by the application of magnetostriction effect and piezo electric effect.

(i) **Magnetostriction effect:-**

Principle:- The change in the dimensions of a ferromagnetic (or) ferrimagnetic material by the application of a magnetic field is known as magnetostriction effect.

The change in length is independent of the sign of the field. But it depends upon the magnitude of the field and nature of material.

If the rod is placed in the alternating current and the frequency of the alternating current coincides with the natural frequency of vibration of rod, resonance occurs and the rod vibrates vigorously producing ultrasonic waves. Ultrasonic waves are now emitted from the ends of the rod.

The frequency of vibration of such a rod is

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

l = length of rod.

E = Young's modulus of the material

ρ = density of the rod material.

Construction :—

1. A short permanently magnetised nickel rod which is clamped in the middle between two knife edges.

2. Coil L_2 wound on the right hand portion of the rod R rod along with a variable capacitor C forms the resonant circuit of the collector tuned oscillator.

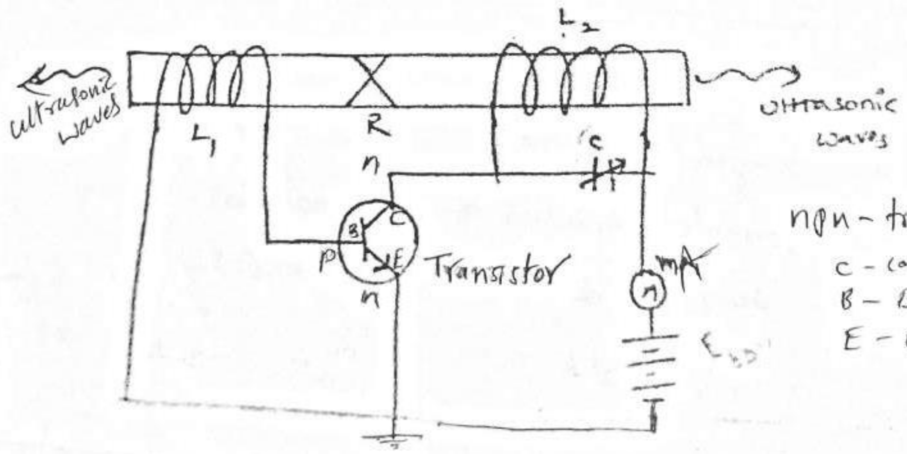
3. coil L_1 wound on the left hand portion of this rod is connected in the base ckt. The coil L_1 is used as a positive feed-back loop.

Working :—

1 when E_{b} is switched on, the ckt L_2C in the collector circuit of transistor sets up a.c of frequency $\boxed{f = \frac{1}{2\pi\sqrt{L_2 C}}}$.

2 Then the coil produces an alternating magnetic field of frequency f along the length of the rod R. The Result is that the rod starts vibrating due to magnetostrictive effect.

3. The vibrations of the rod create ultrasonics which are sent out as shown in fig.



npn - transistor
C - common
B - Base
E - Emitter

The coil L_1 helps in increasing the amplitude of ultrasonic waves.

5. The longitudinal expansion and contraction of the rod R produces an e.m.f in the coil L_1 which is applied to the base transistor.

6. It increases the amplitude of high frequency oscillations in the coil L_2 due to positive feed-back.

7. By adjusting 'C' we can tune the developed a.c frequency with natural frequency of the rod and resonance condition is indicated by the rise of collector current shown in the milliammeter.

Advantages:

1. At low ultrasonic frequencies, large power o/p is possible without the risk of damage of the oscillatory. ckt.

2. The magnetostrictive generator construction is so simple and its cost low.

Limitation:

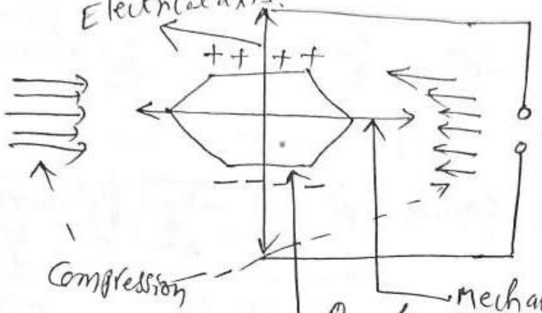
1. It can not generate ultrasonics of frequency above 3000 KHz.

2. we can not get a constant single frequency from these magnetostrictive oscillators.

3. The frequency of oscillating depends greatly on temp.

(4)

Piezo electric effect: when crystals like Quartz, Rochelle salt, tourmaline etc, undergo mechanical deformation (stretching or compression) along the mechanical axis then an electric potential difference is produced along electric axis perpendicular to mechanical axis.



Converse of this effect is also possible.

b) Inverse piezo electric effect – production of ultrasonics.

The circuit diagram is shown in figure.

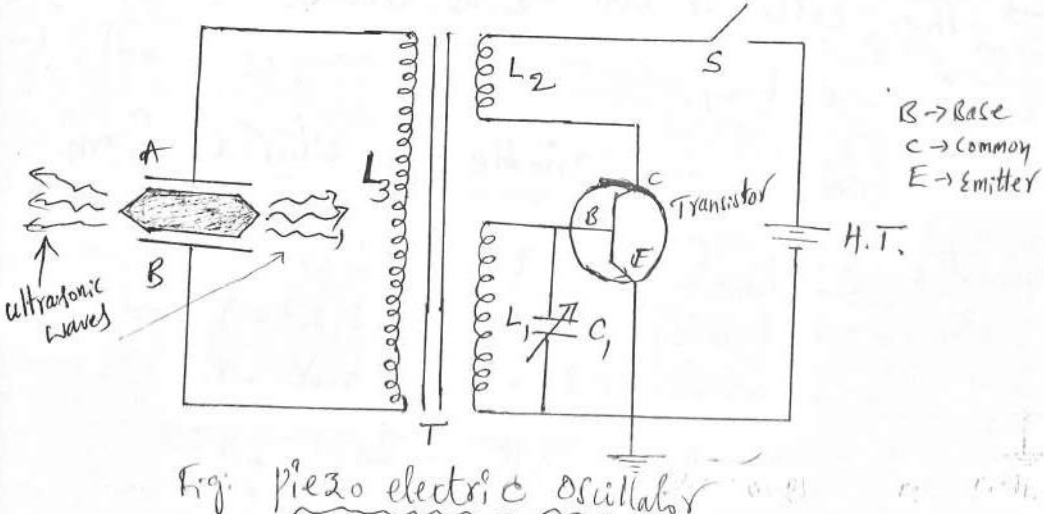


Fig: Piezo electric oscillator

Principle:- If an electric field is applied to one p
faces, the corresponding changes in the dimensions Working:-
the other pair of faces of the crystal are pressed when
This is known as "inverse piezo electric effect" or oscilla
electrostriction effect. with

Construction: The Quartz crystal is placed betw
the two metal plates A and B.

- → The plates are connected to the primary L_3 of a transformer which is inductively coupled to the electronic oscillor.
- → The electronic oscillator circuit is a base tuned oscillator circuit.
- → The coils L_1 and L_2 of oscillator circuit are taken from the secondary of a transformer T.
- → The collector coil L_2 is inductively coupled to base coil L_1.
- → The coil L_1 and variable capacitor C_1 from the tank circuit of the oscillator.

Working :-

When H.T. battery (High Tension) is switched on, the oscillator produces high frequency alternating voltages with a frequency.

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

→ Due to the transformer action, an oscillatory e.m.f. induced in the coil L_3. This high frequency alternating voltages are fed on the plates A and B.

→ Inverse piezo-electric effect takes place and the crystal contracts and expands alternatively. The crystal is set into mechanical vibrations.

→ The frequency of the vibration is given by

$$n = \frac{P}{2l}\sqrt{\frac{Y}{\rho}}$$

where $P = 1, 2, 3, 4 \ldots$ etc for fundamental, first overtone, Second over tone etc.

Y - Young's modulus of the crystal &

ρ - density of the crystal.

→ The variable condenser C_1 is adjusted such that frequency of the applied AC voltage is equal to the natural frequency of the quartz crystal, and thus resonance takes place.

→ The vibrating crystal produces longitudinal ultrasonic waves of large amplitude.

Advantages :-

→ ultrasonic frequencies as high as 5×10^8 Hz or 500 MHz can be obtained with this arrangement.

→ The output of this oscillator is very high.

→ It is not affected by temperature & humidity.

Disadvantages :-

→ The cost of piezo electric quartz is very high.

→ The cutting and shaping of quartz crystal are very complex

(1,3)

Non destructive testing :- (NDT)

Ultrasonic waves were extensively used for nondestructive testing of the material. i.e, detecting the defects (flaws) inside the material without disturbing material properties.

There are several methods to test the material among them pulse - echo method most popular.

Method - I

Pulse - Echo system :-

If there is an air bubble or crack inside the specimen to be tested, the ultrasonic waves are reflected back due to mismatch of acoustic impedanc

Theory & working :-

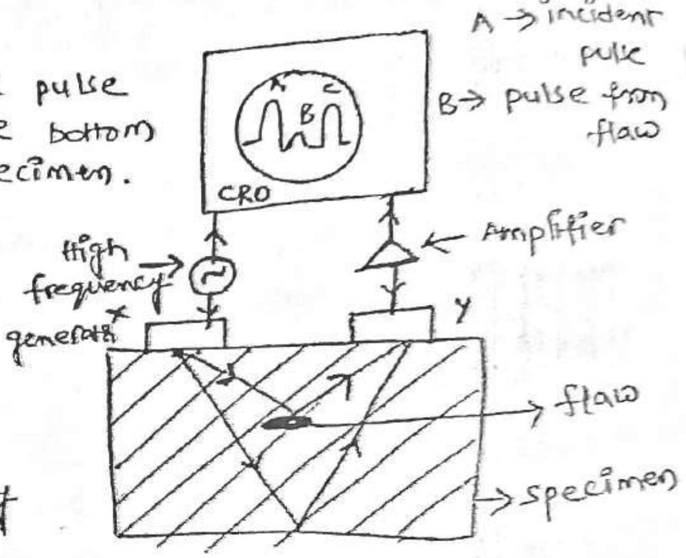
1. A strong pulse of ultrasonics is sent through ~~is sent through~~ the specimen to be tested. At the location of flaw (crack or cavity) there is a change in acoustic impedance and hence the pulse is partily reflected. Hence, it is a weak echo pulse.

2. The incident pulse A the echo pulse from the flaw B and the pulse reflected by the other end of the specimen C are seen in the screen of a cathode ray oscilloscope.

3. If the specimen is free from any flaw, there will be only two pulses A and C.

4. The distance from A, of echo pulse B indicate the nature and location of flaw inside the specimen.

C – Reflected pulse from the bottom of specimen.



Advantages:–

1. Minute flaws can be detected.
2. Location, nature and size of a defect can be accurately determined.

Disadvantages:–

1. No permanent record of the flaw can be obtained, as it can only be observed on the screen of CRO.
2. There should be good mechanical coupling between the piezo electric crystal and specimen to be tested.

Formula: If v is the velocity of ultrasonic waves in the material, then the distance d, of the defect from the top surface of the object is given by

$$d = \frac{vt}{2}$$

Method - II

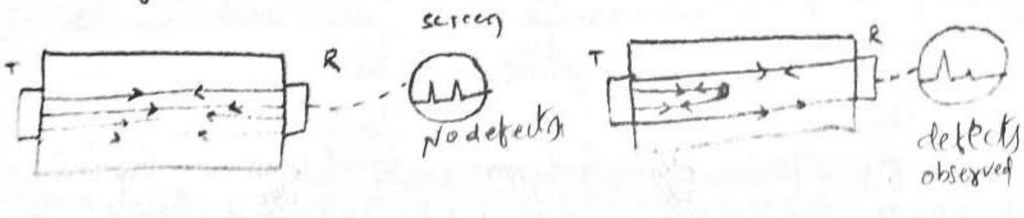
Normal beam pulse through - transmission testing :

Note: In certain cases, the pulse - echo technique may not provide required information. It happens whenever a defect doesn't provide a suitable reflection surface & whenever its orientation is not favourable for detection. In such cases, pulse the through transmission method is adopted.

1. In this method an ultrasonic pulse, from the transducer held at the front surface of the test object, propagates perpendicular to the surface and is transmitted through the boundaries of the object and the surfaces of defects.

2. The transmitted pulses are detected by the second transducer held at the opposite end of the test object.

3. Hence, this method is known as normal beam pulse - through transmission testing method.



Applications of ultrasonic waves

Medical applications

1. Disease treament: ultrasonic therapy has been used to treat diseases such as bursitis, abscesses, lumbago etc.

2. Surgical use: using ultrasonics, we can remove kidney stones and brain tumors with out loss shedding blood. Further we can selectively cut any tissue in our body during an operation.

3. Diagnostic use: ultrasonics are used for detecting tumors and other defects and locating abnormal growths in our body. In the case of breast cancers, one can identify the state of that cancer using ultrasonics in a non distructive manner. Similarly one can identify the twins & any defect in the growth of fetus before delivery.

4. Dental cutting: ultrasonic waves have been found very useful for dental cutting because they make the cutting almost painless and there won't be any mechanical device for cutting.

5. ultrasonic doppler blood flow meters are used to study the blood flow velocities in blood vessels of our body.

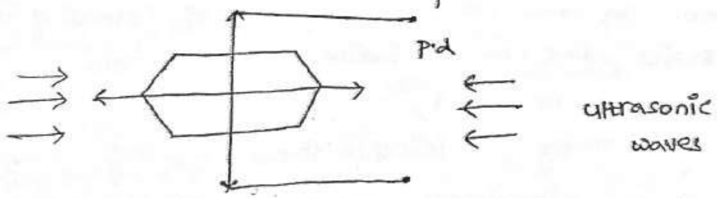
6. Ultrasonic waves used in millitary Applications. (Navigation)
7. Using ultrasonic waves, we can determine depth of oceans.
8) Ultrasonic waves are used in industrial as → cutting → drilling → welding

Detection of ultrasonics! —

The presence of ultrasonic waves can be detected by the following methods:

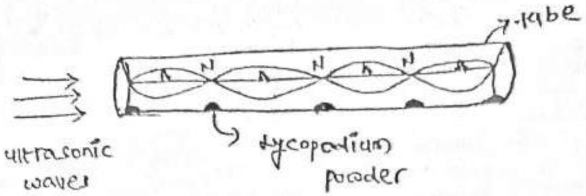
1. Piezo electric detects!

By using the piezo electric effect, we can detect the presence of ultrasonic waves. When the faces of a quartz crystal along the mechanical axis is subjected to ultrasonic, then it undergoes compression and expansion. The opposite faces along the electrical axis, will have induced charges which establishes a potential difference across the faces. This potential difference indicates the presence of ultrasonic waves.

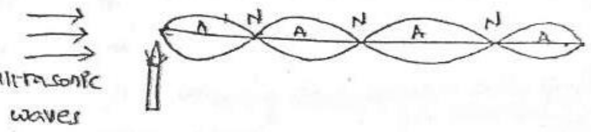


2. Kundt's tube method:—

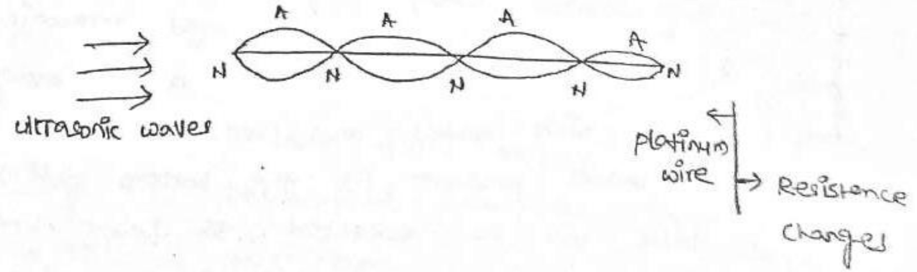
The trasmitted and reflected ultrasonic wave in a Kundt's tube forms a stationary wave pattern with nodes and antinodes. The lycopodium powder present in the bottom position of the tube will be collected as heaps at nodes and dispersed at antinodes. By observing the change in the positions of powder, we can detect ultrasonic waves in the tube.



3. sensitive flame method:- when a narrow sensitive flame is moved in a medium where ultrasonic waves are present. The flame remains stationary at antinode and ~~flic~~ flickers at nodes.



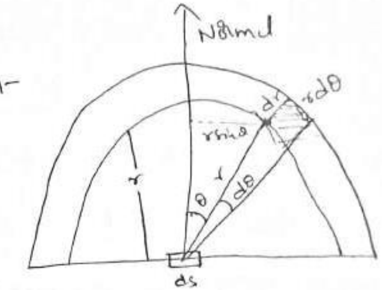
4. Thermal detector method:- when a platinum wire is moved in the medium consists of standing waves of ultrasonics due to variations of temperature at nodes and antinodes, the resistance of wire also changes. By noticing the changing resistance of wire. one can detect the presence of ultrasonic waves.



Sabine's formula for reverberation time

(10M) Let us assume that the sound energy is uniformly distributed all over the room. 'ds' small element of a plane wall AB. Draw two circles of radii r and $r+dr$ containing normal to ds.

Consider the shaded portion in fig between two circles lying between two radii drawn at angles θ and $\theta+d\theta$ with the normal



Area of this shaded element is $rd\theta \cdot dr$

Imagine the whole fig to be rotated about normal through an angle $d\phi$.

The shaded part will travell a distance $r\sin\theta \cdot d\phi$

It traces out small element of volume dv is

$$= r\sin\theta \cdot d\phi \cdot rd\theta \cdot dr$$

$$= r^2 \sin\theta \, d\phi \, d\theta \, dr$$

$\therefore$ Energy in this volume $= Edv$

Energy travelling per unit solid angle $= \frac{Edv}{4\pi}$

The solid angle sustained by the area ds is $\frac{ds\cos\theta}{r^2}$

$\therefore$ Energy travelling towards ds from this volume dv

$$= \frac{Edv}{4\pi} \frac{ds\cos\theta}{r^2}$$

Total energy received by ds $= \int \frac{E\,dv}{4\pi} \frac{ds\cos\theta}{r^2}$

$$= \frac{E\,ds}{4\pi} \int_0^c dr \int_0^{\pi/2} \sin\theta \cos\theta\, d\theta \int_0^{2\pi} d\phi$$

where c is the velocity of sound

$$= \frac{E\,ds}{4}\,c = \frac{Ec\,ds}{4}$$

Total rate of energy absorption by the wall of area S

$$= \frac{Ec\,aS}{4} = \frac{Ec}{4}\Sigma as$$

$$= \frac{ECA}{4}$$

(i) Rate of growth:-

Rate of supply of energy by source

= Rate of growth + Rate of absorption

i.e. $P = \frac{d}{dt}(Ev) + \frac{1}{4}ECA$

$$\frac{P}{V} = \frac{dE}{dt} + \frac{ECA}{4V}$$

put $\frac{CA}{4V} = \alpha$ and multiplying with $e^{\alpha t}$

$$\frac{P}{V}e^{\alpha t} = \frac{dE}{dt}e^{\alpha t} + \alpha E e^{\alpha t}$$

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

Integrating on both sides

$$Ee^{\alpha t} = \frac{4P}{CA}e^{\alpha t} + K$$

where K is the constant of integration and

$t=0$, $E=0$ we get $\boxed{K = -\frac{4P}{CA}}$

$$\therefore \; E e^{\alpha t} = \frac{4P}{CA} e^{\alpha t} + K$$

$$= \frac{4P}{CA} e^{\alpha t} - \frac{4P}{CA}$$

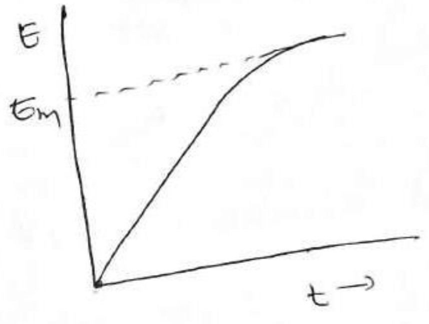
$$= \frac{4P}{CA}\left[e^{\alpha t} - 1\right]$$

$$E e^{\alpha t} = e^{\alpha t}\frac{4P}{CA}\left[1 - e^{-\alpha t}\right]$$

$$E = \frac{4P}{CA}\left[1 - e^{-\alpha t}\right]$$

$$E = E_m\left(1 - e^{-\alpha t}\right) \quad \left(\text{where } E_m = \frac{4P}{CA}\right]$$

The sound energy density grows in an exponential manner with time 't'



Growth

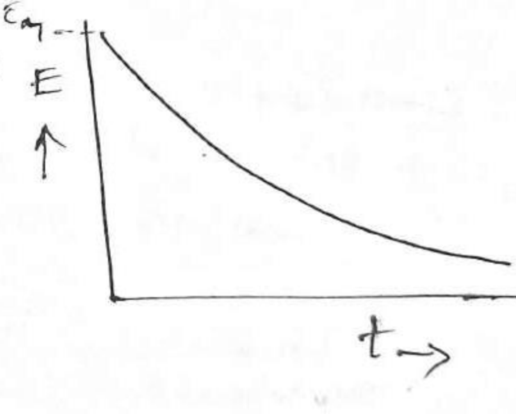
Decay of Sound energy

If the source is cutoff so

$P = 0$ at $t = 0$ and $E = E_m$

then $E e^{\alpha t} = \frac{4P}{CA} e^{\alpha t} + K$ becomes

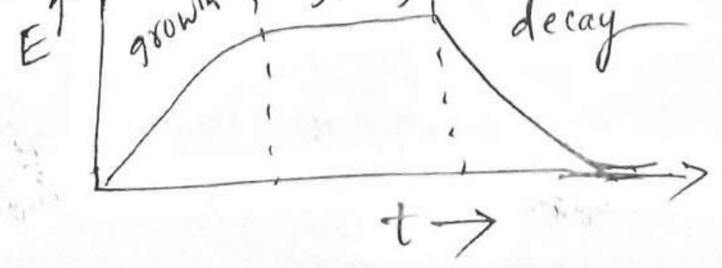
$$|K| = \frac{4P}{CA} = E_m$$



$$E e^{\alpha t} = E_m$$

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

The sound energy density decays exponentially after the source of sound is switched off.



Deduction of Sabine's formula

The reverberation T is defined as the time taken for sound energy density to fall from its steady value to one - millionth value.

$$\therefore \frac{E}{E_m} = 10^{-6} \quad \text{at } t = T$$

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

$$e^{-\alpha t} = 10^{-6}$$

$$\Rightarrow e^{\alpha t} = 10^{6}$$

$$\alpha t = 6 \times 2.3026$$

$$\frac{CA}{4V} t = 6 \times 2.3026$$

$$T = \frac{4 \times 6 \times 2.3026 \times V}{CA} = \frac{0.161\,V}{A}$$

~~where~~ $$\boxed{T = \frac{0.161V}{A}}$$

Limitations :-

1. Sabine's formula doesn't give correct result for absorption coefficient more than 0.2

2. In the case of dead room where $a = 1$, the value of reverberation time should be zero. But Sabine's formula gives a finite and non - zero value.

1. ~2A

Absorption coefficient

Absorption coefficient of a surface is defined as the reciprocal of the ratio of that surface area which absorbs a certain percentage of the incident energy to the area of open window which absorbs the same amount of energy.

Absorption coefficient is also expressed in terms of open window unit (O.W.U)

Ex: $10m^2$ of wall board absorbs the same percentage of incident energy as $4m^2$ of open window, then its absorption coefficient is 0.4 O.W.U $\left(\frac{4}{10}\right)$

Generally absorption coeff of a material (or) surface

$$= \frac{1}{As/Ao}$$

As = Area of the surface absorbing

Ao = Area of the open window

Measurement of absorption coefficient

Method S

The absorption coefficient can be measured in terms of the reverberation time.

T_1 - reverberation time, absorbing material is not in the room

T_2 - reverberation time absorbing material having absorption coefficient a_2 and surface area S_2 kept inside the room.

$$\frac{1}{T_1} = \frac{\Sigma as}{0.16V}$$

$$\frac{1}{T_2} = \frac{\Sigma as + a_2 S_2}{0.16V}$$

$$a_2 = \frac{0.16V}{S_2}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

Knowing the velues S_2 and V, a_2 can be Calculated.

Method II

Suppose we have two sources of sound having maximum intensity of I_0 and I_0'. During the decay of sound, they would reach the fixed minimum audible intensity I_{min} in times T and T'

Such that $I_{min} = I_0 e^{-\alpha T_1}$ for the first soure

$I_{min} = I_0' e^{-\alpha T_2}$ " second source

$$\therefore I_0 e^{-\alpha T_1} = I_0' e^{-\alpha T_2}$$

$$\frac{I_0}{I_0'} = \frac{e^{-\alpha T_2}}{e^{-\alpha T_1}} = e^{-\alpha(T_2 - T_1)}$$

$$= e^{\alpha(T_1 - T_2)}$$

$$\log \frac{I_0}{I_0'} = \log_e e^{\alpha(T_1 - T_2)}$$

$$= \alpha(T_1 - T_2)$$

$$= \frac{CA}{4V}(T_1 - T_2) \quad \left[\because \alpha = \frac{CA}{4V}\right]$$

$$\frac{CA}{4V} = \frac{\log\left(\frac{I_0}{I_0'}\right)}{T_1 - T_2} \Rightarrow A = \frac{4V}{C}\frac{\log\left(\frac{I_0}{I_0'}\right)}{T_1 - T_2}$$

$$as = \frac{4V}{C}\frac{\log(I_0/I_0')}{T_1 - T_2}$$

$$\boxed{a = \frac{4V}{SC}\frac{\log(I_0/I_0')}{T_1 - T_2}}$$

Remedies:

To get optimum loudness in a hall (or) an auditorium, proper amplification of sound be made through sound power amplifiers. During amplification of sound, there should not any distortion of sound by the amplification system.

(c) Focusing and interference effects:

1. If there is any concave surface in the hall, sound is concentrated at its focus region and hence there may be dead space at some other regions. Hence such surfaces must be avoided

2. There should be no interference of direct and reflected waves.

Remedies:

Good absorbing materials and decoration which do not require excessive polishing avoid these defects and ensure sufficient intensity of sound in all regions.

(d) Reflections and Echoes

sounds reflected from walls and other surfaces produce echoes which produce a nuisance effect on the listener ~~because~~

Remedies:

1. The surfaces of the wall should be rough and are not polished

2. The echo effect is avoided by lining the surfaces with sound absorbing materials and by providing a good number of doors and windows

IA

Factors Affecting the Acoustic of Buildings

(e) EC

(a) Reverberation:-

1. The Persistence of sound in the hall eventhough source is cutoff is called reverberation. This is due to successive reflections taking place on the walls of the hall

2. Too much reverberation and too low reverberation may create booming sound and flat sound respectively

3. Thus it is a necessary evil in the acoustics of building.

4. For speeches, the optimum reverberation time ≈ 1-2 Sec and for music it is about 0.5 - 1 Sec

Remedies:-

If the walls are ~~reflecting too~~ lined with absorbing materials like felt, the reverberation time will be reduced. The sound absorbing material should have porous structure light weight and rough surface. porous structure and light weight are useful to absorb the sound energy efficiently and rough surface is used to avoid reflections.

Ex: Thermocool, wood panel, cork, rubber, fur.

(b) Loudness:

Improper (or) non-uniform loudness in a hall will affect the quality of music (or) Lecture in that hall.

(e) Echelon effect

Echelon effect refers to the development of a separate musical note due to combination of echoes having regular phase difference.

If there is staircase with in the hall, the reflections from equally spaced steps at regular ~~spacing~~ intervals of time, produce a seperate sound.

Remedies:- 1. There is no staircase inside the halls.

2. If it is must, the steps made unequally spaced and covered with sound absorbing material.

(f) Resonance effects.

Hollows and crevices sleet their natural frequencies from the sound unequally produced in the hall and rein force them there by producing resonance

Remedies:

1. Resonances are reduced by convex cylindrical segments on walls and ceilings

(g) Noise from the exterior:-

The noises of the vehicular traffic outside the music hall definitely produces a disturbing effect inside.

Remedies:

1. Now a days the halls are completely closed and air conditioned.

2. using of double doors and windows with separa[te] frames and having sound insulating material like o[r] fur (or thermocool between them.

Imp 10M Basic Requirement of Acoustically good hall.

Acoustics of buildings deals with the design of auditorium (or theatre with good acoustics.

for good hall the following conditions are satisfied.

1) The music (or speech performed on the dias should be audible in the entire hall with the amplifier system.

2) The frequency combination of sound be uniform

3) The syllables ought to be clear with out ~~of~~ overlapping

4) There must ~~b~~ not be any pockets of maxima (or minima due to interference

5) The sounds from the exterior must not disturb the Proceedings inside

6) The loudness of the sound should be uniform through out the hall

7) No echo should be present

8) The hall should have proper reverberation time about 1.1 to 1.5 sec

9) Resonance effect should be avoided.

Reve[r]

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Reverberation time of a hall

"The existence of sound in the hall eventhough the Source of sound is cutoff is called reverberation".

Reverberation means the rolling of sound in a hall.

when a sound pulse is produced in a hall it is reflected into a large number of times by the objects present in the hall and wall so that a series of waves of decreasing intensities fall on the listener's ear.

Reverberation time

The time taken by the sound to fall to one million of its original value after the Source of sound is Cut-off.

Sabine Showed that the reverberation time.

$$\boxed{T = \frac{0.16V}{\Sigma as}}$$

V - volume of the hall

Σas — sum of the product of absorption Coefficient of different Surfaces lining the interior of the hall and their respective Surface areas.