Module-5

ACCOUSTICS

"Accoustics" is a branch of physics which deals with generation, transmission and reception of sound energy in different medias.

1) Intensity of sound

Intensity of sound wave is defined as the average rate of flow of energy through unit area normal to the direction of propogation of wave.

Its unit is watt/m^2 (W/m^2).

If 'a' = amplitude of the wave,

n = frequency of the wave,

ρ = density of propogating medium

c = velocity of sound wave in propogating medium

then the expression for intensity:

$$\boxed{I = 2\pi^2 a^2 n^2 \rho c}$$

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were, $I \propto a^2$

The logarithamic scale of intensity of audible sound waves varies from 10^{-12} to $10\ w/m^2$.

2) Loudness

Loudness is the characteristic of sound by virtue of which we distinguish two sounds of same frequency. In other words it is the degree of sensation produced in the ears.

The loudness of a sound wave varies from one listener to another. It is a psychological quantity. therefore it is difficult to measure because it depends upon individual listener.

The loudness of a sound is directly related to intensity 'I' and is proportional to log of intensity of ~~same~~ sound.

ie, $L \propto \log I$

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3) Phone

The unit of loudness level is phon. To measure the loudness of sound, a standard source of frequency 1000 Hz is used. A sound wave whose loudness is to be determined is compared with this standard source. The comparison is as follows:

Let a source of sound whose loudness is to be measured is placed near to the standard source. For comparison, the loudness of standard source is increased until its loudness becomes equal to that of the source. The intensity level of the standard source is measured in decibels (dB). If the intensity level is 'N' dB above the standard value, the equivalent loudness of given source is represented as 'N Phon'.

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4) Absorption coefficient

All material absorb certain amount of sound energy. The degree of absorption is different for different materials {Absorption coefficient of a material is defined as ratio of sound energy absorbed by surface to that of total incident sound energy on the surface:}

$$\text{Absorption coefficient} = \frac{\text{sound absorbed by surface}}{\text{Total sound energy incident on surface.}}$$

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The absorption coefficient is measured in open window unit. (owu) or sabines.

g: Let $10m^2$ of a carpet absorb same amount of sound energy as absorbed by $1m^2$ of open window. Then, the absorption coefficient of carpet is $\frac{1}{10} = 0.1$ owu

5) Reverbation

The sound produced in a room or a hall suffers multiple reflections from various objects -

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like the walls, ceiling, floor, furnitures etc...
In addition to the direct sound a listener hears a series of sound reflected from various objects, even after the source of sound is stored.

The phenomenon of persistence of ~~was~~ audible sound due to multiple reflections from the ceiling, floor, walls and other material objects in an enclosure, even after source is stopped is called Reverberation

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6) Reverberation Time

It is defined as the time taken for the sound to decrease below the min. audibility (60dB) from the instant when the source of sound is cutoff.

Reverberation time depends on following factors:

1) The total absorption caused by all objects,

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ceiling, walls etc...

2) Intensity of sound.

3) Volume of enclosure.

4) Frequency of sound.

5 Significance of Reverberation

1) In sound reflective room, it will take longer time for the sound to die away and the room is said to be accoustically live. ~~In a~~

2) In a sound absorbent room, the sound will die away quickly and room will be described as acoustically dead.

3) In a room with long reverberation time for sound creates difficulty to the audience to understand words of a speech.

4) Rooms that are good for speech and music typically have a reverberation time b/w 1.5 to 2 secs

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5) A room with more reverberation time is desirable for music.

Sabine's Formulae

Sabines derived an expression for reverberation time of an auditorium. consider a source of sound in a room of volume 'V'. The sound energy spread out uniformly throughout the hall. and get reflected and absorbed by the ceiling, floor, walls and other objects. After multiple reflections the energy density becomes uniform throughout the volume of room and sound becomes deiffuses within the room. Assume, the sound source is shut off at t=0 secs, after t= t secs the intensity of sound reduced to 10^{-6} of its max. intensity (reverberation time).

Expression for reverberation - $\boxed{'T' = \frac{0.163\,V}{A}} \boxed{= \frac{0.163V}{\Sigma as}}$

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It is known as sabine's formulae.

were, A→ total absorption coefficient, V→ volume of room.

$a_1, a_2 \ldots a_n$ is the absorption coefficient of surfaces

$s_1, s_2 \ldots s_n$.

Reveberation time T is directly ~~proptio~~ proportional to volume V and inversely proportional to absorption coefficient A.

Factors affecting accoustics of a building

- An accoustically good hall means the one in which every syllable and musical notes reaches at every point of the hall with an audible level of loudness and quickly dies away to make room for next syllable or group of notes.

Factors affecting accoustics of building are as follows:

i) echos

when direct and reflected sound waves coming from

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the same source with different interval about $\frac{1}{7}$ secs produces echos. The ~~sound source, with time interval~~ reflected sound arriving earlier than $1/7$ secs raises loudness while those arriving later produces echos.

Echos can be avoided by covering the long distant walls and high ceiling with absorbent materials.

2) Resonance Effect

some flexible materials inside the hall gets vibrate according to some frequency of the note of the music. When the frequency of vibration is equal to the original note results resonance. Hence, certain tones of the signal will be reinforced and interfere with the original sound. This is called as resonance effect. This can be avoided by fixing the flexible materials suitably for damping resonant vibrations.

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3) Excessive Reverberation

It is produced by multiple reflection of sound by different parts of the room.

This can be reduced by making the floor, wall, ceiling etc... by rough or sound absorbing materials.

4) Focusing due to spherical portions of walls and ceiling

Due to architectural designs, a hall may have concave, spherical or cylindrical portions. Sound after reflection from these curves concentrate at its focal points, were the intensity of sound is high. while some other portions no sound reaches at all.

Remedy

There should not have curved surface, if there is curved surface it should be covered with absorbent material.

Echelon Effect

When the sound is reflected by staircases, any

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regular spacing of reflecting surfaces causes reflection of sound waves at different types. This produces an interference effect with max. intensity at some points and min. intensity at some other points in the hall. This effect is called Echelon effect. This can be avoid be covering the step or the reflecting space by sound absorbents such as carpet.

Extraneous Noise

The unwanted noise created either in outside or inside the hall is called extraneous noise. Outside noises can be reduced by providing ventilations with sound absorbing materials or by properly oiling, providing bearing etc.. to fan or other materials.

Accoustically fit buildings.

The branch of science which deals with the planning of building or an auditorium with best audibility of sound to the audience is called

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acoustics of buildings. A good auditorium must have following properties:

1) sound produced at one point must be audible and well heard at all point without echos.

2) sound should be enough loud to all points in the hall.

3) Continuous sounds of speech must be distinctly heard without over lapping.

4) The reverberation time should be adjust proper. ie, reverberation time for speech is adjusted from 0.5 to 1 seconds, And for music 1 to 2 secs.

5) There should not be focusing and interference of sound waves from any portion of hall.

6) the boundaries should be sufficiently sound proof to avoid extraneous noise.

7) There should not be echelon effect and resonance in building.

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Ultrasonics

The sound waves whose frequency ranges from 20 Hz - 20 kHz is called audible range to human ear.

The sound waves whose frequency > 20 kHz are called ultrasonics. Ultrasonic waves having small wavelength and exhibit some unique properties in additional to general properties of audible sound waves.

Properties of ultra sounds

1) It can be propogated in different modes through the same material.
2) Like light waves it exhibit reflection, refraction, diffraction, interference...
3) ultrasonics can be propogated with different speed in different medium (velocity of ultra sound in air 350 m/s where as in water 1500 m/s)
4) ultrasonics are highly energetic waves. Hence it

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can produce heat effect in the medium.

5) ultrasonics can accelerate some chemical reacns.

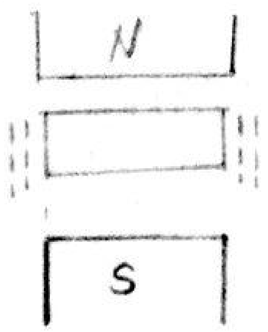
6) ~~The resist~~ Accoustics impedence of diff. medium is different for ultrasonics.

Production of ultrasonics

1) Magneto striction method

It is discovered by Joule in 1847.

when a ferromagnetic material in the form of a bar is subjected to an alternating M.F, then the bar undergoes expansion and contractions at a frequency equal to the frequency of applied M.F. This effect is known as magneto striction method. As a result, bar emits longitudinal ultrasonic waves in to surrounding medium.



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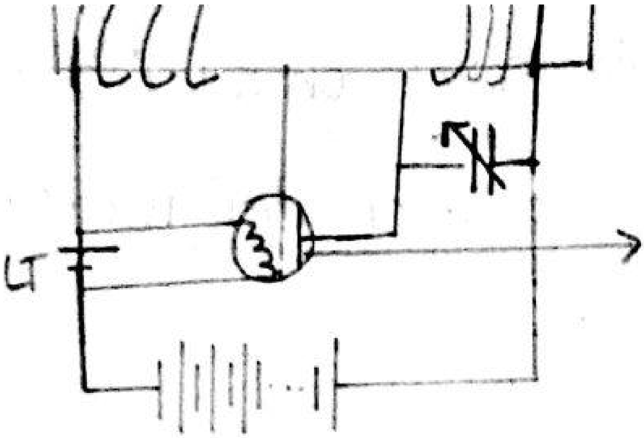

A ferromagnetic bar is inserted through coils A and B as shown in fig. when the rod is magnetised and demagnetised with the alternating current passing through A and B, length of the rod varies accordingly and its free ends produces ultrasonic. If the frequency of vibrating rode is equal to the frequency of applied current, resonance occurs, and amplitude of vibrations become very high and produces ultrasonic waves. The frequency of ultrasound produced by this method depends on length 'l' of rod and density 'ρ' and young's modulous 'Y'.

$$\frac{1}{2}\sqrt{\frac{Y}{\rho}}$$

$$\boxed{\nu = \frac{1}{2l}\sqrt{\frac{Y}{\rho}}}$$

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Thus, by varying length of the bar, ultrasonic waves of any desired frequency can be generated.

2) Piezo-electric method

When an alternating P.D is applied b/w two opposite faces of a piezo electric crystals such as quartz, tourmalline etc..., the crystal oscillates in the direction ⊥r to the direction of applied P.D and ultrasonic waves are produced. It is discovered by J. Curie and P. Curie in 1880.

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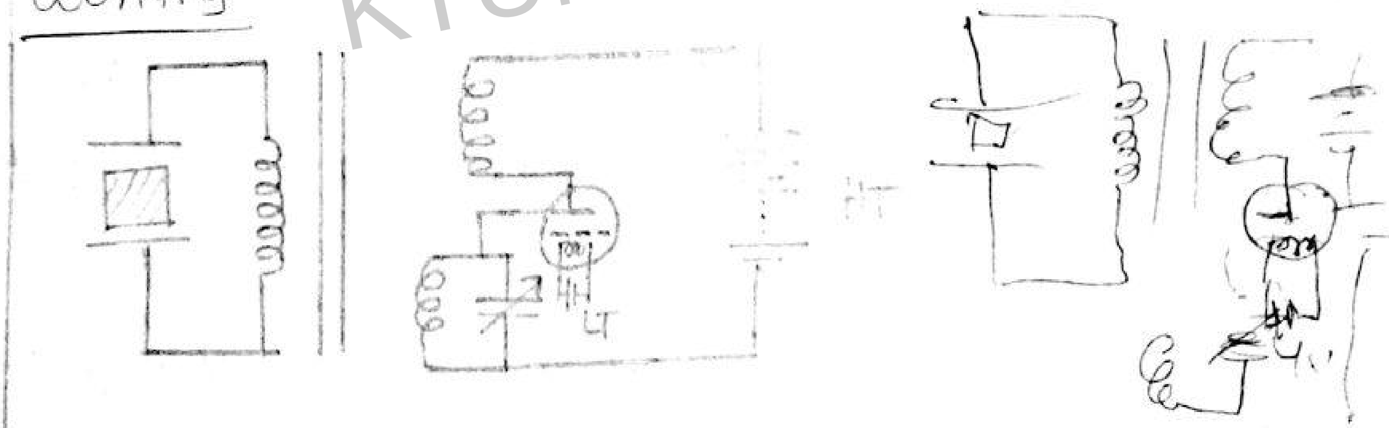
Working



When an oscillatory voltage is applied across crystal, it vibrates and ultrasonic waves are produced in medium. The oscillated frequency is adjusted to matches with natural frequency of crystal, inorder to produce max.

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amplitude. To avoid sparking at quartz plate, a spark gap is put ||el to it.

Detection of ultrasonics

- Peizo electric detector

when a pair of phases of a piezo electric crystals like quartz is subjected to ultrasonic waves, charges develop across opp. pair of phases $\perp^{r}$ to the first. These charges are amplified an amplifier and then detected by suitable detector.

- Thermal Detectors

If a probe of fine platinum wire is placed in the region of ultrasonics, we get compressions, rarefaction very rapidly at nodes. So the platinum probe is ultimately heated and cooled resulting in change of resistance, which may be detected by suitable experiments and find the presence of ultrasonics.

- Sensative flame method

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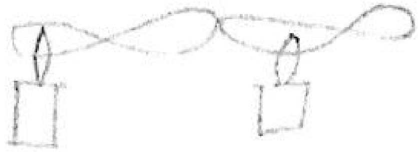
ultrasonics will change intensity of flame. Suppose we move a flame through the region were the ultrasonics are spread. The flame at nodal points is stiff and blue, whereas at antinode is ~~corodent~~ rotten and yellow.



Applications of ultrasonics

1) In non destructive testing

The method of inspecting internal structure of objects without any distruption or impairment of their servicability is called NDT.

eg: Pulse echo method, sonogram, ultrasound scanning method, submarine detection, ultrasonic flow detector, mixing of liquids, welding.

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