[Acoustics of Building].

-: Sound

Sound:- In physics sound is taken to denote the physical cause of sensation. The source of Sound is always a body which is in State of rapid vibration.

sound

musical Sound	Noise.
the sound which produced the pleasure sensation on the ear.	the Sound of Complex nature having an irregular period and amplitude.

It is due to spl. property like Periodicity, regularity and Continuity.
Instrument like Veena, guitar, etc.

loudness : It is a characterstics of Sound due to which a particular sound appear to be feeble or loud. the loudness of sound is related to the Sensitivity of our ear

Intensity of sound:- It is the quality of sound energy crossing unit area surrounding a point in Unit time
the area being normal to the direction of propogation of Sound.

Unit of Intensity:- W/m^2

Our ear Can't hear the sound of intensity less than 10^{-12} W/m^2

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Unit of loudness :-

The basis of loudness Scale is weber-Fechner law.

It state that the degree of the sensation is directly proportional to the logrithm of the stimulus producing it.

If L is the degree of loudness due to intensity I, then

$$L = K \log I \quad \text{--- (1)}$$

where K is Const.

$$\frac{dL}{dI} = \frac{K}{I} \quad \text{--- (2)}$$

from eq (2) it is clear that as the total intensity of sound increases there is a rapid decrease in Sensitiveness of the ear.

The loudness is measure in bels.

If in eq (2) K is take as either 1 or 10

Intensity level 10. with

$$K = 1$$

$$L = \log_{10} 10 = 1 \text{ bel.}$$

with

$$K = 10$$

$$L = \log 10 = 10 \text{ decibel.}$$

Decibel is one-tenth of a bel and is given by the symbol. dB.

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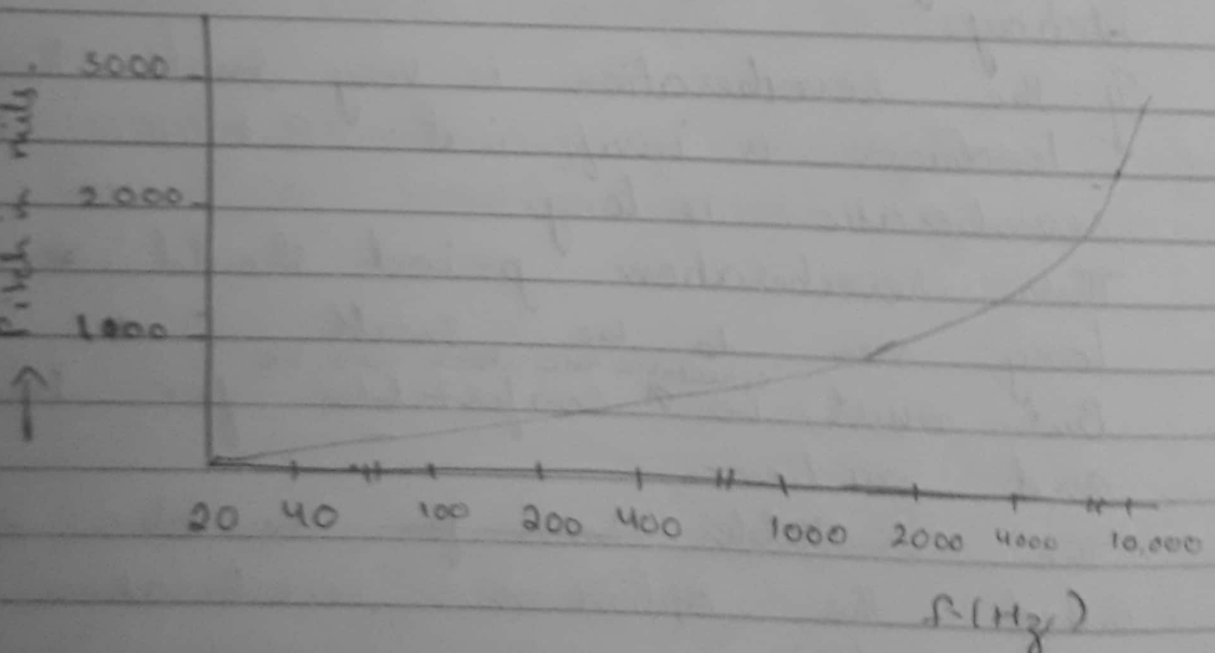
The upper limit q hearing is Called the threshold q feeling or pain threshold.
threshold q feeling also depend upon the frequency q sound.

A sound q loudness level 120 dB

pitch

The pitch is defined as the characteristics q sound by which a particular sound appears to be grave or shrill.

The greater the frequency the higher is the pitch but the pitch and frequency are not proportional.



frequency vs pitch q a sound having loudness level q 60 phones.

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Reverberation:- The persistance of audible sound waves after the source has ceased to emit the sound is called reverberation.
clearly,
if this reverberation of syllable persist for a long duration so as to prolong this sound while several other successive syllabus are being pronounced, intelligiblity will suffer.

Generally a syllable take about 0.2 sec to decay.
If the reverberation is very small then the loudness is insufficient. But, the time reverberation is long.
Thus, reverberation period should neither be too long nor to be small.
But, must be situatable time which may be confortable for both speakers and audience.
The suitable ~~time for~~ ~~se~~ value of time is called the optimum reverberation time of an auditorium.

Professor Sabine show that the optimum period of reverberation time depend on the volume of the room.

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SABINE'S REVERBERATION FORMULA.

Professor Sabine gave an emperical formula for the period of reverberation of a given hall.

Sabine formula for reverberation is given by

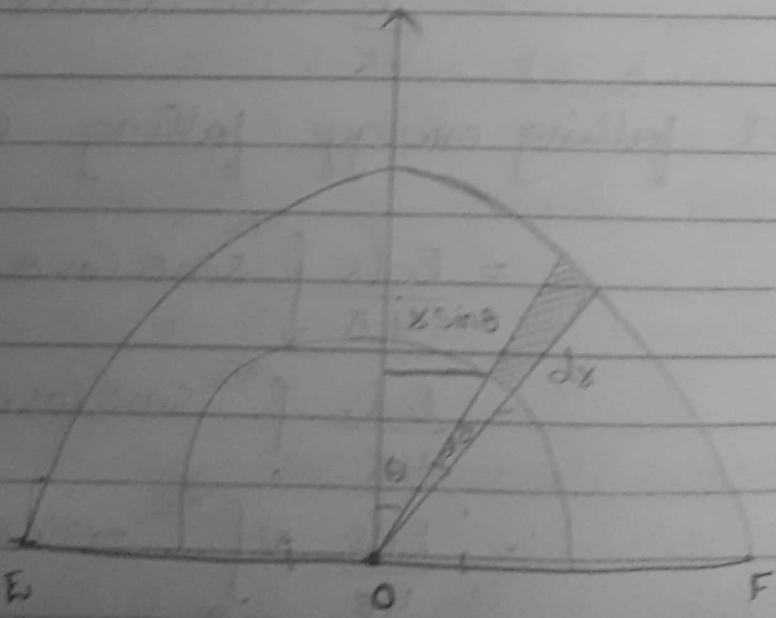
$$T = 0.162\, V/A.$$

V = Volume of hall in m^3.
A = total absorption of sound in hall in metric sabine
i.e

$$A = \Sigma\, as$$

A = absorption Co-efficient of the Surfaces of surface area's present in a hall.

Let us Consider a wall EF of absorption Co-efficient and Consist of Several Segment of Several area ds.



Daigram to find T.

The shaded portion is at a distance of $r \sin\theta$. From the normal ON drawn to LF.

Volume enclosed $= r\sin\theta \times d\theta \cdot d\phi$ — (2)

If E is the energy density of sound in the hall.

$$\text{Volume} = E r^2 \sin\theta\, d\theta\, d\phi \quad \text{— (3)}$$

The amount of sound energy going towards ds is

$$ds = \frac{E}{4\pi} r^2 \sin\theta\, d\theta\, dr\, d\phi \quad \text{— (4)}$$

The solid angle suspended by the segment ds with this volume.

$$= \frac{ds \cos\theta}{r^2} \quad \text{— (5)}$$

$$= \frac{E}{4\pi} r^2 \sin\theta\, d\theta\, dr\, d\phi \cdot ds \frac{\cos\theta}{r^2}$$

$$= \frac{E}{4\pi} \sin\theta\, d\theta\, dr\, d\phi\, ds \cos\theta \quad \text{— (6)}$$

the net ~~falling~~ sound energy falling on ds per second

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

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

$$= \frac{E\,ds}{4\cancel{\pi}} v \int_0^{\pi/2} 2 \times \sin\theta \cos\theta\, d\theta.$$

$$= \frac{E\,ds}{4} v \int_0^{\pi/2} 2 \sin\theta \cos\theta\, d\theta.$$

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$$= \frac{E\,ds}{4} v \int_0^{\pi/2} \sin 2\theta \, d\theta$$

$$= \frac{E}{4} ds\, v \left[-\frac{\cos 2\theta}{2} \right]_0^{\pi/2}$$

$$= \frac{E}{4} ds\, v \quad \text{—— (7)}$$

If a is the absorption Coefficient of element ds the energy absorbed per second.

$$= \frac{E}{4} a\, ds\, v$$

Total sound absorbed by wall. $EF = \frac{E}{4} vA.$

$A = \Sigma\, a ds$ is the total absorption.

the rate of growth of energy at any instant

$$= \frac{d(EV)}{dt}$$

$$= V \frac{dE}{dt} \quad \text{—— (8)}$$

rate of absorption of sound energy $= \frac{EvA}{4}$

$$V \frac{dE}{dt} + \frac{EvA}{4} = P \quad \text{—— (9)}$$

When the energy ~~the~~ source reaches a steady state value

$E = E_m$, $\frac{dE}{dt}$ becomes zero

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from eq (9)

$$E_m = \frac{4P}{A} \quad \text{--- (10)}$$

eq (10) Can be rearranged as

$$\frac{dE}{dt} + \frac{VA}{4V} E = \frac{P}{V} \quad \text{- (11)}$$

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

$$\alpha = \frac{VA}{4V}$$

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

$$\frac{dE}{dt} e^{\alpha t} + \alpha E e^{\alpha t} = \frac{4P}{VA} \alpha \cdot e^{\alpha t}$$

$$\frac{d(Ee^{\alpha t})}{dt} = \frac{4P}{VA} \alpha e^{\alpha t} \quad \text{--- (12)}$$

$$Ee^{\alpha t} = \frac{4P}{VA} e^{\alpha t} + M \quad \text{--- (13)}$$

where M is the Const. integration

Rate of growth of sound energy

rate of growth of sound energy is obtained by using (13) by putting $t=0$ $E=0$

$$M = -\frac{4P}{VA}$$

$\therefore$ The rate of growth of sound energy at any instant t as given by eq (13) can be written as.

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

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

$$E = E_m(1 - e^{\alpha t}) \quad \text{—— (14)}$$

Now, at $t = 0$ and $P = 0$
eq (13) gives.

$$Ee^{\alpha t} = M = E_m. \quad \text{—— (15)}$$

$$E = E_m e^{-\alpha t}. \quad \text{—— (16)}$$

$$\frac{E_m}{10^6} = E_m e^{-\alpha t} \quad \text{—— (17)}$$

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

Taking log on both sides

$$6 \log_e 10 = at$$

$$t = \frac{6 \times 2.303 \times \log_{10} 10}{\alpha} \quad \text{—— (18)}$$

we know $\alpha = \frac{VA}{4V}$

$$t = \frac{6 \times 2.303 \times 4V}{VA} \quad \text{— (19)}$$

choosing the velocity of sound 340 m/s

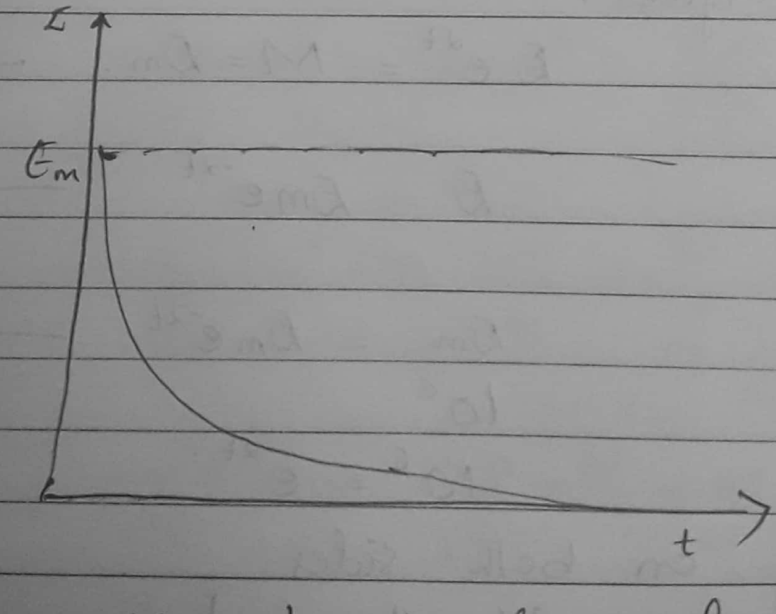
$$\frac{6 \times 2.303 \times 340 \times 4}{}$$

$$t = \frac{6 \times 2.303 \times 4V}{340}$$

$$t = \frac{0.162\,V}{A} \quad \text{— (20)}$$

Thus the reverberation time is obtained by using eq 20

Rate of decay of sound



from eq 16 it is observed that the decay of sound is expopnential decrease very rapidly initially and slowly later on