Chapter 3

Acoustics

Acoustics of Building

The branch of physics which deals with the planning of a building or a hall with a view to provide best audible sound to the audience is called acoustics of building.

Factors Affecting the Acoustics of Building

1. **Extraneous Noise**
   - There may be penetration of sound between rooms.
   - For this the wall must be covered with sound absorbing material and doors must have heavy curtains.

   (There should be no penetration of sound between rooms)

2. **Loudness**
   - The loudness of sound may vary with position.
   - To make proper loudness every where, wooden reflecting surface can be kept above the speaker. Low ceiling is also help full in reflecting sound towards audience.

   (The sound must sufficiently be loud every where).

3. **Echelon effect**
   - If there is a series of steps between floors or levels (or a set of railing), the sound produced in front of such a structure may produce a musical note due to regular successive echoes of sound. Such an effect is called Echelon effect. If this note is in audible range, the listener will hear it prominently.
   - To avoid Echelon effect steps are covered with carpet.

   (There should be no Echelon effect)

4. **Focusing**
   - There may be concentration of sound or a zone of silence in any part of the hall.
   - For uniform distribution curved surface and projection should be designed. One method is to make the wall in front of audience parabolic with speaker at its focus.

   (Their must be proper focusing of sound every where in the hall.

5. **Echo**
   - Echo is a reflection of sound that arrives at the listener with a delay after the direct sound. The distortion of sound takes place because of echo.
   - The average interval between two syllables spoken by a person is about 0.2 sec. These walls and ceilings should be made in such a way that the reflection of sound takes place in more than 0.2 sec. Otherwise it creates a confusion due to overlapping of direct and reflected sound.

   (There should not be echo).

6. **Resonance**
   - The resonance of any audio frequency note causes the sound of different intensity than that of direct one.
   - For the hall of large size, the resonance frequency is much below the audible limit and harmful effects due to resonance will not be present.

7. **Reverberation**
   - The persistence of sound for some time even when the source of sound has ceased is called Reverberation. This is due to the multiple reflection of sound from various part of the hall.
   - It can be controlled by proper maintenance of absorbing material i.e. providing window, doors, carpets on the floor, heavy curtains, using full capacity of audience etc.

Reverberation

The persistence of sound for some time even when the source of sound has ceased is called reverberation.

Causes:

i. The fall in intensity of the sound produced in room is exponential and so it will take longer time to become zero.

ii. Due to multiple reflection from walls, ceilings and floor or other material, the sound reverberates inside the hall for longer time.

Time of Reverberation

The duration for which the sound can be heard after the source has ceased to produce the sound is called reverberation time.

OR: The time taken by sound intensity to fall it's intensity equal to one millionth of its original value (i.e. by a factor of 10^{-6}) is called time of reverberation. (i.e. time to fall loudness by 60dB)

Absorption of Sound

Coefficient of absorption of sound for the surface of material is defined as the ratio of sound energy absorbed by the surface to the sound energy absorbed by an equal area of a perfect absorber such as an open window.

The unit of absorption coefficient is Sabine. The sound energy absorbed by 1. sq.ft. of perfect absorber is called one Sabine.

If A is effective surface area for surface having total surface area S. The absorption coefficient 'α' is given by the relation

$$A = \alpha.s.$$

If α_1, α_2, ... α_n are absorption coefficient for each reflecting surface and s_1 , s_2, s_3 ...... are corresponding area, then the average value of absorption coefficient is.

$$\alpha = \frac{\alpha_1 s_1 + \alpha_2 s_2 + \ldots\ldots\ldots +}{s_1 + s_2 + s_3 + \ldots\ldots} = \Sigma \frac{\alpha_i s_i}{s_i}$$

$$\Rightarrow \alpha = \frac{\Sigma \alpha_i s_i}{S}$$

Sabine's Formula for Reverberation Time

Let 'I' be the average intensity of sound at any instant of time and δI be the fall in intensity due to absorption in a small instant of time δt, then,

$$\delta I = - \alpha \, n \, I \, \delta t \qquad .....(1)$$

where, n = number of reflection of sound waves per second

α = absorption coefficient of all absorbing surfaces.

It has been shown by Jaeger that sound travels an average distance 4V/S between successive reflections.

where V = volume of the hall

S = Total surface area of the reflecting surface.

If v is the velocity of sound, then time between successive reflection is, $\frac{\text{Distance}}{\text{Velocity}} = \frac{4V}{Sv}$.

Therefore, $n = \frac{Sv}{4V}$ .....(2)

putting value of 'n' in equation (1)

$$\delta I = - \alpha \, . \frac{Sv}{4V} I \, \delta t$$

or, $$\frac{\delta I}{I} = - \alpha \frac{Sv}{4V} \delta t$$

It can be written in limit as

$$\frac{dI}{I} = - \frac{\alpha S v}{4V} dt$$

Let I_o be the value of intensity at t = 0 and I_t be it's value after time 't'. then integrating above equation.

$$\int_{I_o}^{I_t} \frac{dI}{I} = - \frac{\alpha S v}{4V} \int_{o}^{t} dt$$

or, $$[\ell n \, I]_{I_o}^{I_t} = \frac{-\alpha Sv}{4V} . t$$

$$\Rightarrow \quad I_t = I_o \exp\left(- \frac{\alpha S v}{4V} . t \right)$$

For reverberation time, $t = T$, $I_t = I_o / 10^6 = I_o \times 10^{-6}$

Therefore,

$$10^{-6} = \exp\left(\frac{-\alpha S v}{4V} . T\right) \Rightarrow \exp\left(\frac{\alpha S v}{4V} . T\right) = 10^6$$

or, $$\frac{\alpha S v}{4V} . T = ln\,(10^6) = 6\,ln\,(10)$$

$\therefore$ $$T = \frac{6\,ln\,(10) \times 4 \times V}{\alpha\,Sv} = \frac{55.262V}{\alpha\,S\,v}$$

Since $v = 350$ m/sec at room temp.

Therefore, $T = \dfrac{0.158V}{\alpha S}$ in S.I unit ....(3)

The is called Sabine formula.

If we put $v = 1120$ ft/sec, the expression for reverberation time will be,

$$T = \frac{0.05V}{\alpha\,S} \text{ in F.P.S.}$$

This shows that Reverberation time is directly proportional to the volume of auditorium and inversely proportional to absorption coefficient and total surface area.

For good acoustics of a hall, the reverberation time should have appropriate value. If it is too large, there may be multiple reflections and over lapping of sound cousing confusion to listner. If it is too small, the sound vanishes instanteneously and gives the dead effect. The suitable value of reverberation time is 1.03 sec for a hall of 10,000 cu ft capacity.

Equation (3) is called Sabine's formula.

Ultrasonics

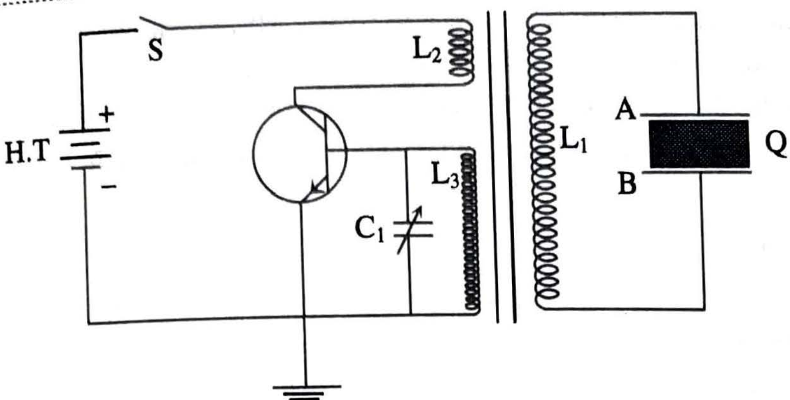
The longitudinal mechanical wave of frequency greater than 20 KHz are called ultrasonic waves. These are not audible.

Audible waves (Ordinary sound): The longitudinal mechanical waves whose frequency lies in the range 20 Hz to 20KHz and can produce sensation of hearing in our ears are called audible waves and those having frequency less than 20 Hz are called infrasonic.

Production of Ultrasonic Waves

1. **Piezo - Electric Generation**

   If mechanical pressure is applied to the opposite faces of certain crystal slices (such as quartz, Rochelle salt) cut in a way that their faces are perpendicular to optic axis, the other pair of opposite faces develop opposite electric charges resulting a potential difference. This effect is called piezo - electric effect.



Conversely, if a periodic potential is applied to the opposite faces of the crystal, the periodic change in dimension of crystal would take place. This periodic change in length of crystal produces ultrasonic waves. For the generation of ultrasound one can supply the periodic voltage of frequency equal to that of ultrasound which is to be produced.

The experimental circuit diagram is as shown above 'Q' is a thin slice of crystal cut with its opposite faces are perpendicular to optic axis. The crystal is placed between two metal plates A and B. The plates A and B are connected to the primary of transformer which is coupled inductively to the oscillator circuit. The variable condenser C_1 is adjusted so that frequency of the oscillatory circuit is equal to the natural frequency of one of the modes of vibration of crystal. This will ensure mechanical vibration in the crystal due to linear expansion and contraction.

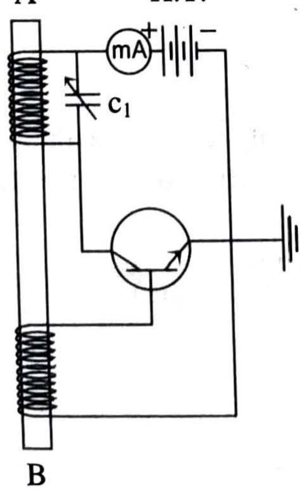
The frequency of vibration is.

$f = \frac{n}{2l}\sqrt{\frac{Y}{\rho}}$, where, n = 1, 2, 3.... (modes of vibration)

Y = Young's modulus of elasticity.
ρ = density of the crystal
l = length of crystal.

2. **Magnetostriction generator**

When a ferromagnetic material in the form of bar, is subjected to alternating magnetic field, it expands and contracts alternately with twice the frequency of the applied magnetic field. These longitudinal expansions and contraction produce ultrasonic waves.



The experimental arrangement is as shown in figure. AB is a bar of ferromagnetic material. Initially bar is magnetized by passing current. The condenser C_1, is adjusted so that the frequency of oscillatory circuit is the same as the natural frequency of bar.

Since the rod is open at both end, for fundamental mode of vibration, frequency is given by

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

Where

l = length of rod

ρ = density of rod

Y = Young's modulus of elasticity.

Application of ultrasonic waves

1. **Directional signaling:** ultrasonic's are used for signaling to find the depth of sea, to detect the position of submerged rocks, submarines ice bergs etc.
2. **Sound signaling:** Because of their high frequency, it is possible to radiate large amount of sound energy which spread out in all direction.
3. **Elastic symmetry of crystal:** A solid crystal act like an acoustic grating. If ultrasonic's are applied to an isotropic crystal, we get diffraction pattern from which elastic symmetry of crystal can be studied.
4. **Chemical use:** These waves are useful to form stable emulsion of immiscible liquids like water and oil. These waves are used for making alloys of uniform composition. Water can be decomposed into hydrogen ion.
5. **Biological use:** Small animals like frogs, fish, bacteria etc are killed or maimed because of exposure to ultrasonic. Yeast cells loss their power of reproduction when exposed to ultrasonic.
6. **Medical use:** They are used in ultrasound scanning of body. The rate of flow of blood can be measured by determining Doppler shift of R.B.C., bloodless brain surgery.
7. **Thermal use:** The application of ultrasonic waves on certain substance can produce necessary amount of heat.

Solved Examples

1. **The time of reverberation of an empty hall and with 500 audience in the hall is 1.5 sec and 1.4 sec respectively. Find the reverberation time with 800 audience in the hall.**

Solution:

According to question, $1.5 = \dfrac{0.158\ V}{\alpha.S}$ ....(1)

and $1.4 = \dfrac{0.158\ V}{\alpha.S + 500}$ ....(2)

Dividing equation (1) by (2)

$$\frac{1.5}{1.4} = \frac{\alpha S + 500}{\alpha S} \Rightarrow 1.5\,\alpha S = 1.4\alpha S + 700$$

$$\Rightarrow \alpha S = 7000$$

From equation (1), $V = \frac{1.5 \times \alpha S}{0.158} = \frac{1.5 \times 7000}{0.158} = 66455.7$

Therefore, time of reverberation with 800 audience,

$$T_3 = \frac{0.158\,V}{\alpha S + 800} = \frac{0.158 \times 66455.7}{7000 + 800} = 1.346 \text{ sec}$$

2. **The volume of a room is 600 m^3, wall area of room is 220m^2, the floor and ceiling area each is 120 m^2. If average absorption coefficient for walls is 0.03, for ceiling is 0.80 and for floor is 0.06 calculate average absorption coefficient and reverberation time.**

Solution,

Here, $V = 600 \text{ m}^3$

Absorption due to wall $= \alpha_1 S_1 = 220 \times 0.03 = 6.6$

Absorption due to floor $= \alpha_2 S_2 = 0.06 \times 120 = 7.2$

Absorption due to ceiling $= \alpha_3 S_3 = 0.80 \times 120 = 96$

Total absorption $\alpha S = \alpha_1 s_1 + \alpha_2 s_2 + \alpha_3 s_3 = 109.8$ Sabines

$$T = \frac{0.158\,V}{\alpha s} = \frac{0.158 \times 600}{109.8} = 0.86 \text{ sec}$$

Average absorption coefficient, $\alpha = \frac{\Sigma \alpha S}{\Sigma S} = \frac{109.8}{220 + 120 + 120}$

Therefore, $\alpha = 0.239$

3. **A lecture hall with a volume of 4500 m^3 is found to have a reverberation time of 1.5 sec. What is the total absorbing power of all the surfaces in the hall? If the area of the sound absorbing surface is 1600 m^2, calculate average absorption coefficient.**

Solution:

Volume of hall, $V = 4500 \text{ m}^3$

Reverberation time, $T = 1.5$ sec

Since $T = \frac{0.158\,V}{\alpha S} \Rightarrow \alpha S = \frac{0.158 V}{T} = \frac{0.158 \times 4500}{1.5} = 474$

Absorbing power of all surfaces, $\alpha s = 474$ Sabine.

Area of absorbing surface, $S = 1600 \text{ m}^2$

Average absorption coefficient, $\alpha = \frac{\alpha S}{S} = \frac{474}{1600} = 0.3$

4. **What is the reverberation time for a hall with length 12m, breadth 11m, and height 9m. If the coefficients of absorption of walls, ceiling and floor are 0.02, 0.04 and 0.08 respectively.**

Solution:

Volume of the hall, $V = 12 \times 11 \times 9 = 1188 \text{ m}^3$

Area of floor = Area of ceiling = $l \times b = 132\ m^2$

Area of walls = $l \times h + l \times h + b \times h + b \times h = 2\,(l+b).\,h$

$= 2\,(12 + 11) \times 9 = 414\ m^2$

Total absorption, $\alpha s = 414 \times 0.02 + 132 \times 0.04 + 132 \times 0.08 = 24.12$

Reverberation time, $T = \dfrac{0.158\,V}{\alpha s} = \dfrac{0.158 \times 1188}{24.12} = 7.78$ sec

5. **Calculate the reverberation time of small hall of 1500 m^3 having seating capacity of 120 persons when i) The hall is empty and ii) with full capacity of the audience for the following data.**

Surface	Areas	Coefficient of absorption
plastered wall	112 m^2	0.03
wooden floor	130 m^2	0.06
plastered ceiling	170 m^2	0.04
wooden doors	20 m^2	0.06
cushioned chairs	120	0.5
Audience	120	0.44

Solution:

The absorption due to plastered wall = $\alpha_1 s_1 = 112 \times 0.03 = 3.36$

The absorption due to wooden floor = $\alpha_2 s_2 = 130 \times 0.06 = 7.8$

The absorption due to plastered ceiling = $\alpha_3 s_3 = 170 \times 0.04 = 6.8$

The absorption due to wooden doors = $\alpha_4 s_4 = 20 \times 0.06 = 1.2$

The absorption due to cushioned chairs = $\alpha_5 s_5 = 120 \times 0.5 = 60$

The absorption due to audience = $\alpha_6 s_6 = 120 \times 0.44 = 52.8$

1. Total absorption with out audience = 79.16

   Therefore, $T = \dfrac{0.158\,V}{\alpha s} = \dfrac{0.158 \times 1500}{79.16} = 2.99$ sec

2. Total absorption with full capacity of audience = 79.16 + 52.8 = 131.96

   $T = \dfrac{0.158\,V}{\alpha s} = \dfrac{0.158 \times 1500}{131.96} = 1.8$ sec

6. **Entry of people in an auditorium of volume 1,60,000 cu. ft and total absorption of 1000 sq. ft of open window raises the absorption by 600 sq. ft. Find the change in reverberation time.**

Solution:

Volume of auditorium, V = 160, 000 cu. ft

Total absorption, αs = 1000 sq.ft

$T = \dfrac{0.05\,V}{\alpha s} = \dfrac{0.05 \times 160000}{1000} = 8$ sec

Total absorption due to entry of people = 1000 + 600 = 1600 sq.ft

Area of floor = Area of ceiling = $l \times b = 132\ m^2$

Area of walls = $l \times h + l \times h + b \times h + b \times h = 2\,(l+b).\,h$

$= 2\,(12 + 11) \times 9 = 414\ m^2$

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6. **Entry of people in an auditorium of volume 1,60,000 cu. ft and total absorption of 1000 sq. ft of open window raises the absorption by 600 sq. ft. Find the change in reverberation time.**

Solution:

Volume of auditorium, V = 160, 000 cu. ft

Total absorption, αs = 1000 sq.ft

$T = \dfrac{0.05\ V}{\alpha s} = \dfrac{0.05 \times 160000}{1000} = 8$ sec

Total absorption due to entry of people = 1000 + 600 = 1600 sq.ft

Area of floor = Area of ceiling = $l \times b = 132\ m^2$

Area of walls = $l \times h + l \times h + b \times h + b \times h = 2\ (l+b).\ h$

$= 2\ (12 + 11) \times 9 = 414\ m^2$

Total absorption, $\alpha s = 414 \times 0.02 + 132 \times 0.04 + 132 \times 0.08 = 24.12$

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1. Total absorption with out audience = 79.16

   Therefore, $T = \frac{0.158\ V}{\alpha s} = \frac{0.158 \times 1500}{79.16} = 2.99$ sec

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   $T = \frac{0.158\ V}{\alpha s} = \frac{0.158 \times 1500}{131.96} = 1.8$ sec

6. **Entry of people in an auditorium of volume 1,60,000 cu. ft and total absorption of 1000 sq. ft of open window raises the absorption by 600 sq. ft. Find the change in reverberation time.**

Solution:

Volume of auditorium, V = 160, 000 cu. ft

Total absorption, αs = 1000 sq.ft

$T = \frac{0.05\ V}{\alpha s} = \frac{0.05 \times 160000}{1000} = 8$ sec

Total absorption due to entry of people = 1000 + 600 = 1600 sq.ft

Hence, Reverberation time, $T = \dfrac{0.05 \times 160000}{1600} = 5$ sec

Change in reverberation time = 8 – 5 = 3 sec

7. **A hall with floor is 15 × 30 m^2 along with height of 6m in which 500 people occupy upholsters seat and the remainder sit on wooden chair, optimum reverberation time for orchestral music is 1.34 sec and absorption coefficient per person is 0.44**
   a. **Calculate the total absorption to be provided by the walls, floor and ceiling when the hall is fully occupied.**
   b. **Calculate the reverberation time if only half upholstered seats are occupied. (α = 0.02 for each wooden chair)**

Solution:

Volume of hall, $V = 15 \times 30 \times 6 = 2700\ m^3$

Area of walls $= 2 (l + b) h = 2 (15 + 30) \times 6 = 540\ m^2$

Area of floor $= 15 \times 30 = 450\ m^2$

Area of ceiling $= 15 \times 30 = 450\ m^2$

We have, $T = \dfrac{0.158\ V}{\alpha s} \Rightarrow \alpha s = \dfrac{0.158\ V}{T}$

$$\alpha s = \frac{0.158 \times 2700}{1.34} = 318.36$$

Total absorption, $\alpha s = 318.36$

Absorption due to audience = 500 × 0.44 = 220

a. Absorption provided by walls, floor and ceiling = 318.36 – 220
   = 98.36

b. If only half seats are occupied, then absorption due to 250 people = 250 × 0.44 = 110 and absorption due to 250 wooden seats = 250 × 0.02 = 5
   Total absorption for this case = 318.36- 220 + 110 + 5
   = 213.36

$$T = \frac{0.158\ V}{\alpha S} = \frac{0.158 \times 2700}{213.36} = 2.0 \text{ sec}$$

8. **A room has dimension of 6m × 4m × 5m find,**
   1. **mean free path of sound wave in the room.**
   2. **The number of reflections made per second by the sound wave with the walls of the room (Take velocity of sound in air = 350 ms^{-1})**

Solution:

i. Mean free path $(\lambda) = \dfrac{4 \text{ (volume of room)}}{\text{Total surface area}} = \dfrac{4V}{S}$

   Here volume of the room $(V) = 6 \times 4 \times 5 = 120\ m^3$

   and total surface area $(S) = 2 (lb + bh + hl)$

   $= 2 (6 \times 4 + 4 \times 5 + 6 \times 5) = 148\ m^2$

Mean free path (λ) = $\frac{4 \times 120}{148} = 3.243$ m

ii. The no of reflection made per second, N = $\frac{\text{velocity of sound}}{\text{mean free path}}$

$$= \frac{350}{3.243} = 107.9$$

$$= 108$$

9. A quartz crystal of thickness 0.001 m is vibrating at resonance. Calculate the fundamental frequency. Given, young's modulus for quartz (y) = 7.9×10^{10} N/m^2 and density of quartz (ρ) = 2.650×10^3 kg/m^3

Solution:

We have the relation for fundamental frequency,

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

In this case, $y = 7.9 \times 10^{10}$ N/m^2

$\rho = 2.650 \times 10^3$ kg/ m^3

$l = 0.001$ m

Therefore, $f = \frac{1}{2 \times 0.001}\sqrt{\frac{7.9 \times 10^{10}}{2.65 \times 10^3}} = 2.73 \times 10^6$ Hz

10. The time of reverberation of an empty hall is 1.5 sec with 500 audiences present in the hall the reverberation time falls to 1.4 sec. Find the number of persons present in the hall if the reverberation time falls down to 1.312 sec.

Solution:

For first case, $1.5 = \frac{0.158\ V}{\alpha s}$ ......(1)

For second case, $1.4 = \frac{0.158\ V}{\alpha s + 500\ \alpha_m}$ ....(2) α_m = absorption coefficient for a person

For third case, $1.312 = \frac{0.158\ V}{\alpha S + n\alpha_m}$ .... (3) n = number of person

Dividing (1) by (2)

$$\frac{1.5}{1.4} = \frac{\alpha s + 500\ \alpha_m}{\alpha s} = 1 + \frac{500\ \alpha_m}{\alpha s}$$

$\Rightarrow$ $500\ \alpha_m = 0.07143\ \alpha s$ ....(4)

Again dividing (1) by (3),

$$\frac{1.5}{1.312} = \frac{\alpha s + n\alpha_m}{\alpha s} = 1 + \frac{n\alpha_m}{\alpha s}$$

$\Rightarrow n\alpha_m = 0.1433\ \alpha s$ .....(5)

Again dividing (5) by (4)

$$\frac{n}{500} = \frac{0.1433}{0.07143}$$

n = 1003

11. A lecture hall of volume 12×10^4 m^3 has a total absorption of 13200 m^2 of open window unit. Entry of students into the hall raises the absorption by another 13200 m^2 of open window unit. Find the change in reverberation time.

Solution:

Volume of the hall, V = 12×10^4 m^3

Total absorption, αs = 13200 m^2 of open window unit.

Reverberation time (T) = $\frac{0.158\ V}{\alpha s} = \frac{0.158 \times 12 \times 10^4}{13200} = 1.44$ sec

Due to the entry of students the raise in absorption = 13200 m^2

New total absorption, αs = 13200 + 13200 = 26400 m^2

New, reverberation time,

$$T = \frac{0.158\ V}{\alpha s} = \frac{0.158 \times 12 \times 10^4}{26400} = 0.72 \text{ sec}$$

Therefore, change in reverberation time = 1.44 - 0.72 = 0.72 sec

12. The size of an empty assembly of bell has dimension $20 \times 15 \times 5$ cm^3 and the reverberation time is 3.5 sec. What area of the wall should be covered by curtain cloth to reduce the reverberation time by 2.5 if the absorption coefficient of curtain cloth is 0.5. Also calculate the average absorption coefficient of the bell.

Solution.

Volume of the bell, V = $20 \times 15 \times 5 \times 10^{-6}$ m^3 = 0.0015 m^3

We have,

$$T = \frac{0.158\ V}{\alpha\ S}$$

or, $3.5 = \frac{0.158 \times 0.0015}{\alpha\ S}$

$\alpha S = \frac{0.158 \times 0.0015}{3.5} = 6.77 \times 10^{-6}$

Total surface area of bell = 2 ($lb + lh + bh$)

= 2 ($20 \times 15 + 20 \times 5 + 15 \times 5$)

= 950 cm^2

= 0.095 m^2.

Now, Absorption coefficient of curtain cloth (α_1) = 0.5

Then, New reverberation time T_1 = 3.5 – 2.5 = 1 sec

$$T_1 = \frac{0.518\ V}{\alpha\ S + \alpha_1\ S_1}$$

$$1 = \frac{0.158 \times 0.0015}{6.77 \times 10^{-6} + 0.5\ S_1}$$

Or, $0.5\ S_1 = 2.37 \times 10^{-4} - 6.77 \times 10^{-6}$

Or, $S_1 = \frac{2.30 \times 10^{-4}}{0.5}$

$\therefore$ $S_1 = 4.60 \times 10^{-4}$ m^2

Also, average absorption coefficient of bell, $\alpha = \frac{\Sigma\alpha S}{\Sigma S} = \frac{6.77 \times 10^{-6}}{0.095} = 7.12 \times 10^{-5}$

Exercise

1. What is reverberation? Derive Sabine's reverberation formula and explain its significance.
2. What is ultrasonic waves? Discuss a method for the production of Ultrasonic wave.
3. How are ultrasonic wave produced and detected? How these wave are used to detect cracks in metals. Mention some of the properties of ultrasonic waves.
4. Distinguish between ultrasonic and infrasonic. Discuss briefly the application of ultrasonic waves (a) finding the depth of a sea (b) signaling.
5. Derive the necessary equation for reverberation time and mention the factors affecting the acousting of building.
6. Explain the magnetostriction method of production of ultrasonics.
7. What is reverberation? Discuss the factors that determines reverberation time in an auditorium.
8. Define absorption coefficient of sound. Derive relation between reverberation time and absorption coefficient for acoustically good hall.
9. Give an account of bad acoustic properties of a hall. Derive the expression for reverberation time in a good acoustics of a hall.
10. Give the physical principle of the generation of Ultrasound by using piezoelectric material.
11. What is reverberation? Explain the causes of reverberation in theatre and how can it be reduced.
12. How ultrasonic wave are used for the distance measurement.
13. What are the factors that affect the build up and decay of sound level in an auditorium? Define reverberation time.
14. Calculate the reverberation time in a hall measuring 40×100×20ft. With the following parameters (i) 7500 sq. ft of plaster, $\alpha_1 = 0.03$ (ii) 600 sq. ft. of wood and floor etc $\alpha_2 = 0.06$ (iii) 400 sq. ft. of glass $\alpha = 0.025$ (iv) 600 seats, $\alpha_4 = 0.3$ (v) Audience of 500 persons $\alpha_5 = 4.0$ per person.
15. A lecture hall with a volume of 45,000 cu. ft. is found to have a reverberation time of 1.5 sec. What is total absorbing power of all the Surface in the hall? If the area of the sound absorbing surface is 8000sq. ft. Calculate average absorption coefficient.
16. A hall has a volume of 80000 sq. ft. Its absorption coefficient is equivalent to 1000 sq. ft. of an open window. Calculate the reverberation time.
17. The volume of room is 980 m^3. The wall area of the room is 150 m^2, ceiling area 95 m^2 and floor area 90m^2. The average sound absorption coefficient (i) for wall is 0.03 (ii) for ceiling is 0.80 and (iii) for the floor is 0.06. Calculate the average sound absorption coefficient and reverberation time.

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