APPLIED PHYSICS - I

S.Y. B.Sc.

Semester III

2nd Revised Edition

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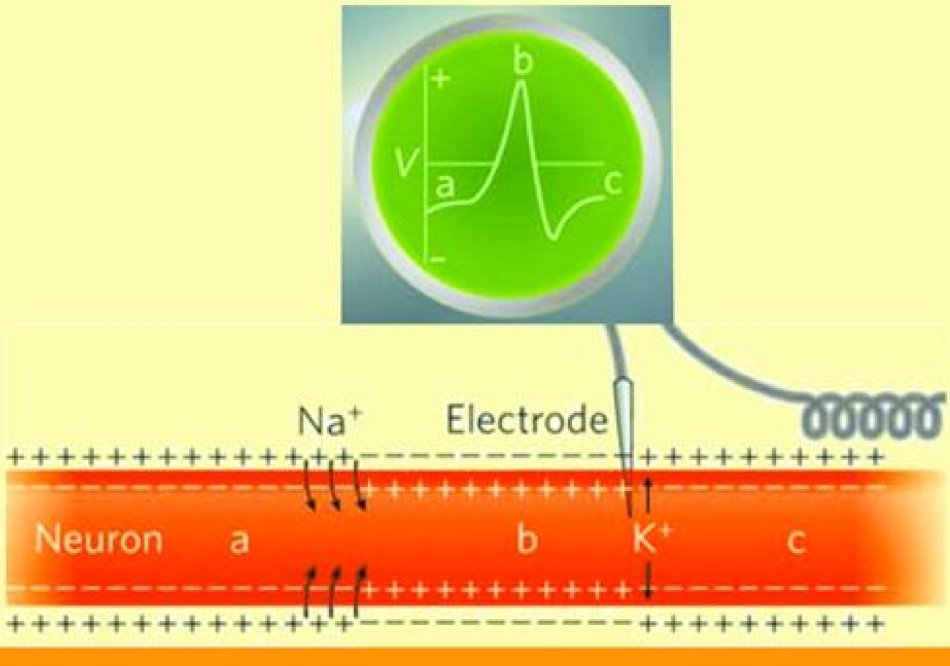

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PREFACE

Third course in S.Y.B.Sc. course in each semester offers interdisciplinary application-oriented topics. This offers as a choice to all learners across various combinations. This course will seek to foster a spirit of multidisciplinary approach in learning. Considering this in view we as authors tried our best to present this Applied Physics-I book, which is prepared according to new revised syllabus prescribed by the University of Mumbai for S.Y.B.Sc., Semester III, USPH303: APPLIED PHYSICS-I course.

We hope that this will be extremely useful to the students in understanding the subject. We welcome the suggestions for improvement.

We thanks the Director, Shri. K.N. Pandey and the team of Himalaya Publishing House Pvt. Ltd. for bringing this book.

Mumbai **AUTHORS**

SYLLABUS

USPH303 : Applied Physics - I

This paper consists of three modules (units) designed in a way so as to offer interdisciplinary and application oriented learning.

Learning Outcomes: On completion of this, it is expected that:

(i) Students will be exposed to contextual real life situations.

(ii) Students will appreciate the role of Physics in interdisciplinary areas related to materials, Bio Physics, Acoustics etc.

(iii) The learner will understand the scope of the subject in Industry and Research.

(iv) Experimental learning opportunities will faster creative thinking and a spirit of inquiry.

Unit I: Acoustics, Lasers and Fibre Optics **(15 Lectures)**

(1) Acoustics of Buildings: Reverberation, Sabine's formula (without derivation) Absorption coefficient, Acoustics of Buildings, factors affecting Acoustics of Buildings, Sound distribution in an auditorium.

(2) Laser: Introduction, Transition between Atomic Energy States (without derivation), Principle of Laser, Properties of Laser, Helium–Neon Laser, Application of Laser, Holography.

(3) Fibre Optics: Light propagation through Fibres, Fibre Geometry, Internal reflection, Numerical Aperture, Step-Index and Graded-Index Fibres, Applications of Fibres.

Unit II: Biophysics **(15 Lectures)**

Introduction, definition, History and scope of biophysics, biological fluids, physico-chemical properties, viscosity, surface tension, pH, osmosis, osmotic pressure. Diffusion, Ficks' laws of diffusion, dialysis, Cell is unit of life, fundamental understanding prokaryotic and eukaryotic cell structure and function, eukaryotic cell membrane, Fundamentals of transport process through biological membrane, membrane channels. electrical properties of cell, Action potential, propagation of action potential, methods of measurement of action potential, Nernst equation, Golman equation, The Hodgkin-Huxely model of action potential, voltage clamp technique, Patch clamp technique, cell impedance and capacitance.

Unit III: Materials – Properties and Applications **(15 Lectures)**

Introduction to Materials

Classification of Materials based on structures (Crystalline and Amorphous, single crystal, polycrystalline and nanomaterials) and Functionality (Conducting, insulating, superconducting, reflecting, transmitting etc.)

Types of Materials: Metals and alloys, Ceramics, Polymers and Composites, Thin Films, Nanomaterials; Some Physical and Chemical methods of materials synthesis. **(5 L)**

Properties of Materials

Electrical Properties: Review of energy band diagram for materials - conductors, semiconductors and insulators, Electrical conductivity in metals, semiconductors and insulators (dielectrics), effect of temperature on conductivity.

Optical Properties: Reflection, refraction, absorption and transmission of electromagnetic radiation in solids.

Magnetic Properties: Origin of magnetism in solids (basic idea), Types of magnetic order (paramagnetism, diamagnetism, antiferro magnetism, ferromagnetism, ferrimagnetism), magnetic hysteresis. **(6 L)**

Applications

Optical Materials: LEDs, OLEDs, LCDs, Flat Panel Displays, Optical Fibers.

Dielectric Materials: Piezoelectric, Ferroelectric and Pyroelectric Materials.

Magnetic Materials: Soft Magnets (Transformer steels), Hard Magnets for Permanent Magnets, Magnetic Recording and Storage. **(4 L)**

CONTENTS

Paper III : Applied Physics - I

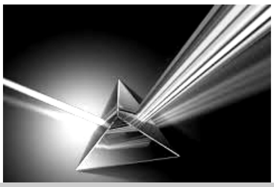
Unit I: Acoustics, Lasers and Fibre Optics

Unit II: Biophysics

Unit III: Materials – Properties and Applications

Chapter - 1

Unit I



Acoustics of Buildings

1.1 Introduction

Acoustics of building is the part of science of physics which deals with the control of sound in buildings, cinema hall, auditoriums etc. The purpose of this control is to create conditions by which people can hear with comfort. It is necessary to consider the principles of sound and the factors affecting the architectural acoustics.

Sometimes a buildings are constructed such that there is no consideration about the acoustical properties of rooms and halls. Such a constructions leads that, people cannot hear the sound with comfort. So proper design and planning is needed for construction of hall or room so as to hear the best sound to every audience in the hall.

The branch of Physics which deals with the planning, design and construction of a hall, auditorium or a room to provide the best audible sound to every audience is called Acoustics of Building.

In this chapter, we will be focusing on essential features about good acoustics, coefficient of absorption, Sabine formula and sound distribution in a hall.

1.2 Essential Features about Good Acoustics

Prof. W.C. Sabine scientifically tackled the problem of speech and music in a hall. According to him an auditorium must be acoustically good. So he studied the problem and laid down the essential features about good acoustics.

1. The sound heard in an auditorium or a hall must be sufficiently loud to every part of the hall and there should not be echo.
2. The quality of speech of music must remain same always.
3. There should not be overlapping of successive syllables, for the sake of clarity.
4. The reverberation should be quite proper (~ 1 to 2 seconds)
5. There should be no concentration of sound in any part of the hall.
6. The boundaries should be sound proof to exclude extraneous noise.
7. There should be no echelon effect.
8. There should be no resonance within the building.

1.3 Reverberation and Time of Reverberation

When a sound is produced in a hall or building, it lasts for long time. The listener receives the sound directly from the source and then after subsequently reflection from walls, window, ceiling and floor of the hall. The small part of the sound energy is lost at every reflection. Thus, listener receives series of sounds of diminished intensity, which creates confusion to listener.

Reverberation: Reverberation is defied as the persistence or prolongation of sound in a hall even though the sound source is stopped. The prolonged reflection of sound from the walls, ceiling, and floor of the room or hall is called reverberation.

Time of reverberation: The time taken for the sound to fall below the minimum audibility measured from the instant when the source stopped emitting.

Reverberation time or time of reverberation is also defined as the time required for sound to decay 60 dB from its initial level.

Sabine found that the time of reverberation depends upon the size of the hall, loudness of the sound and the kind of music or sound for which hall is to be used.

Acoustically good auditorium or a hall is that where time of reverberation is negligibly small. In case of a speech, series of notes are produced in a hall, each one has its own intensity. The rate of decreasing intensity of an impulse should be such as to allow the other without confusion. Hence there should not be any confusion.

It was found that, for a sound of frequency 512 Hz, the time of reverberation is 1 to 1.5 seconds for a capacity of 4500 m^2 hall. To avoid longer time of reverberation, anti-reverberation materials must be used. Porous tiles, asbestos for plastering can be used to reduce reverberation time.

1.4 Sabine Formula

Prof. Wallace C. Sabine (1868-1919) of Harvard University investigated architectural acoustics scientifically, particularly with reference to reverberation time. He deduced experimentally, that the reverberation time is:

- directly proportional to the volume of the hall
- inversely proportional to the effective absorbing surface area of the walls and the materials inside the hall

$$T \propto \frac{V}{\sum aS}$$

where, V is the volume of the hall, 'a' is the absorption coefficient of an area S. If the volume is measured in cubic feet and area in square feet, then the experimentally obtained value of the constant of proportionality, according to Sabine is 0.05. Then,

$$T = \frac{0.05\,V}{\sum aS}$$

If there are different absorbing surfaces of area S_1, S_2, S_3, S_4, etc., having absorption coefficients a_1, a_2, a_3, a_4 etc., then,

$$T = \frac{0.05\,V}{a_1S_1 + a_2S_2 + \dots \dots \dots \dots}$$

If the area is measured in square meters and the volume in cubic meters, then Sabine's formula can be written as: $T = \frac{0.161\,V}{\sum aS}$

Increasing the effective area of complete absorption like, changing the wall materials or adding more furniture may decrease an excessive reverberation time for a hall. But this also decreases the intensity of a steady tone. Also, too much absorption will make the reverberation time too short and cause the room to sound acoustically ‘dead’. Hence, the optimum reverberation time is a compromise between clarity of sound and its intensity.

1.5 Coefficient of Absorption

The coefficient of absorption of a material is defined as the ratio of sound energy absorbed by the surface to that of total incident sound energy on the surface.

$$\text{Thus, Absorption coefficient } (a) = \frac{1}{T} = \frac{\text{sound energy absorbed by surface}}{\text{sound energy incident on the surface}}$$

The standard unit of absorption is taken as the unit area of open window as all the sound falling on open window pass through it, it is assumed that an open window as a perfect absorber of sound.

Thus absorption coefficient is also defined “the rate of sound energy absorbed by a certain area of the surface to that of an open window of same area”.

The method used to measure absorption coefficient is based on determination of standard times of reverberation in the room without and with a standard large sample of material inside the room.

Let T_1 and T_2 be the times of reverberation.

Using Sabine’s formula:

$$\frac{1}{T_1} = \frac{A}{0.161\,V} = \frac{\sum aS}{0.161\,V} \qquad \text{... (1.1)}$$

where, a = coefficient of absorption, S = surface area, V = volume of the room or a hall.

and;

$$\frac{1}{T_2} = \frac{\sum aS + a_1 S_1}{0.161\,V} \qquad \text{... (1.2)}$$

$$\frac{1}{T_2} - \frac{1}{T_1} = \frac{a_1 S_1}{0.161\,V} \qquad \text{... (1.3)}$$

where, a_1 is absorption coefficient of the area.

$$\therefore\ a_1 = \frac{0.161\,V}{S_1}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \qquad \text{... (1.4)}$$

Following table gives absorption coefficient of certain materials.

Material	**Absorption coefficient (a) in OWU**
Glass	0.02
Marble	0.01
Wooden floor	0.06-0.08
Carpets	0.15-0.30
Cushions	0.15-0.18
Brick wall	0.03

(* OWU: Open Window Unit)

1.6 Acoustics of Buildings

Acoustic of building deals with design and construction of hall. Halls or rooms are acoustically poor due to distribution of intensity is not uniform and different frequency of sound interfere at some point and reduces the quality. To get good acoustical building, factors to be considered are; Reverberation time, Focusing and interference, Echoes and Echelon effect, Resonance and Extraneous noise.

If reverberation time is too low, sound disappear quickly and become inaudible. If reverberation time is too high, sound exist for a long period. For the good audibility reverberation time should be kept at an optimum value. It can be reduced by installing sound absorbing materials like windows and openings, arranging full capacity of audience, completely covering the floor with carpets, false ceilings, heavy curtains with folds and decorating the walls with drawing boards, picture boards. Note that if window panels or any other wooden sections are not covered properly, the original sound may vibrate with the natural frequency of them and resonance occurs. This can be minimized by mounting the vibrating materials on non-vibrating and sound absorbing materials, fitting panels properly and eliminated through proper ventilation or by Air-Conditioning. The high absorption or low reflecting surfaces near the sound source lead to Loudness defect. If loudness is low, this defect can be reduced by keeping the speakers at regular distances, properly focusing the sound boards behind speakers, lowering the ceiling and placing reflecting surfaces at necessary places. If loudness is high, the sound absorbents can be placed at noisy places. The reflected sound by the ceiling and wall must be distributed evenly throughout the hall rather it should not be focused at a particular area of the hall. To reduce this focusing effect, the radius of curvature of concave ceiling should be made two times the height of the building and also to cover the curved surfaces with proper sound absorbing materials. Interference effect is caused by interference of direct and reflected wave. This effect is minimized by the usage of uniform painting and absorbent. Sound get scattered by wall, instead of reflection. If the time interval between the direct sound and the reflected sound is less than 1/15 of a second, the reflected sound reaches the audience later than the direct sound and it creates echoes. The new sound produced by repetitive echoes called echelon effect. The regular reflecting surface like stair case may create this effect. Echoes and Echelon effect can be reduced by properly covering the long distance walls, high ceilings with suitable sound absorbing materials and covering regular reflecting surfaces like stair case properly.

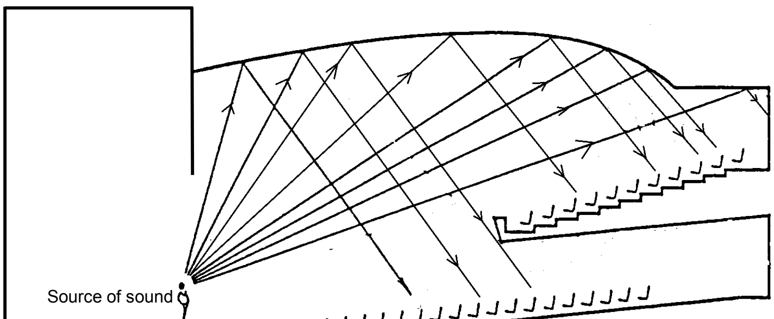


Fig. 1.1: Cross section of auditorium

According to W.C. Sabine, for good acoustics of buildings, the sound energy must be uniformly distributed throughout the hall. Fig 1.1 shows that the reflected sound distributed evenly in the whole auditorium.

1.7 Factors Affecting the Acoustics of Buildings

For acoustically good hall, every syllable or note must reach an audible level of loudness at every point of the hall and quickly die off. Following factors affect the architectural acoustics:

(a) Reverberation: The time of reverberation for a hall should neither be too large nor too small. The preferred value of the time of reverberation is called optimum reverberation time. According to Sabine, standard time of reverberation is;

$$T = \frac{0.161\,V}{A} = \frac{0.161\,V}{\sum aS}$$

Reverberation time can be controlled by;

1. providing windows and ventilators to make the value of the time of reverberation optimum,
2. using heavy curtains with folds,
3. by providing acoustic tiles,
4. by covering the floor with carpets,
5. by full capacity of audience.

(b) Adequate loudness: Sufficient loudness in every portion of the hall is an important factor for hearing. The loudness may be increased by,

1. Use of large sounding boards behind the speaker will help to increase the loudness,
2. Low ceilings will help in reflecting the sound energy towards audience.

(c) Focusing of sound: In an acoustically poor hall, there are regions of silence while there are regions of low or bad distribution of intensity of sound. Thus for uniform distribution of sound energy in an hall following steps should be taken;

1. Ceiling should be low,
2. Use of parabolic reflectors will help to focus sound,
3. The curved surfaces should be covered with absorbing materials.

(d) Absence of echoes: Echo is heard when direct and reflected sound waves coming from the same source reach the listener with time interval of (1/15) second. This will lead confusion to listener as direct sound and echo overlap on each other. Echoes are reduced by long distant walls and high ceilings with very good absorbing materials.

(e) Echelon affect: The effect is an important factor affecting the acoustics of buildings. This effect is the production of a musical sound of definite frequency due to reflection of sound from various regular structures such as railings, stairs etc. This occurs due to successive echoes from these regular structures reaching the listener. The echelon effect can be overcome by spreading a carpet over the steps and/or making the spacing of steps irregular. Also by making the spacing of railing irregular on ceiling echelon effect can be minimized.

(f) Extraneous noise and sound isolation: Noise is an unwanted sound. The noise may be due to high frequency of sound or intensity or due to both. The noise produced displeasing effect on the ear. There are three types of noises which are troublesome, (i) air borne, (ii) structure borne, (iii) Inside noise. The prevention of the transmission of noise inside or outside the hall is known as sound isolation also known as sound proofing.

1.8 Sound Distribution in an Auditorium

From an acoustical perspective, auditorium presents a unique design challenge. The two primary uses of the auditorium; dramatic and musical, each have inherent acoustical requirements.

To function well, the auditorium must be conducive to its intended use. An auditorium with proper acoustics encourages the audience to contemplate the acoustical content of the sound source. An auditorium with poor acoustics is immediately apparent and detracts from the presentation.

Auditorium Design Criteria

Successful acoustics in the auditorium are built on four pillars:

1. The background noise level must be low enough so as not to interfere with the perception of the desired sound,
2. The desired sound(s) must be sufficiently loud,
3. The sound within the auditorium should be distributed with considerable uniformity (this statement implies the avoidance of focusing, echoes, and areas of deficient sound level when compared with other positions in the room), and
4. The reverberation time should be well-suited to the intended use of the space.

1. Background Noise

A common metric used to characterize background noise is known as the noise criterion rating. This is a single number rating given to the measured background sound levels within a space. The background sound, which contributes to the noise criterion rating, can originate from any number of sources, including the air handling equipment, noise in adjacent rooms, nearby traffic, lighting dimmers, etc.

When designing to achieve the acceptable noise criterion rating for an auditorium, knowledge of another acoustical metric is required. The sound transmission class rating for a wall or roof indicates the ability of that composite construction to resist the transmission of sound from one side of the construction to the other. A high Sound Transmission Class (STC) rating indicates the composite construction in question (wall or roof) functions well in preventing undesired sounds from entering the auditorium. An auditorium with high STC walls limits sound generated in adjacent spaces from entering the auditorium, and conversely, high STC walls limit sound generated in the auditorium from entering adjacent spaces.

2. Reinforcement of the Desired Sound

Although sound reinforcement is typically a phrase used to describe the electronic equipment that accomplishes this task, it is important to understand that the successful auditorium itself functions to reinforce the desired sound. This reinforcement is accomplished through properly placed hard reflecting surfaces. These surfaces provide early reflections, which reinforce the direct sound arriving at the listeners' ears.

3. Distribution of Sound

The distribution of sound within the auditorium is not surprisingly related to how the space is articulated, that is both the room's shape and the room's interior finish materials. The distribution of sound over the audience area is dependent on the efficiency by which sound travels from the stage house to the main space of the auditorium. Fig 1.1 shows that the reflected sound distributed evenly in the whole auditorium. In the case of a musical performing ensemble, a stage enclosure is essential for assisting in the projection of sound into the auditorium.

4. Reverberation Time

The design of an auditorium with the correct reverberation time is perhaps the most delicate of the four acoustic design concepts presented here. The reverberation time of a given spaces is, roughly defined, the time it takes for sound to decay from a given level to the threshold of audibility. The space must be reverberant enough to meet expectations for musical performances, but not too reverberant so as to compromise speech intelligibility. Experience with relatively reverberant spaces reveals that good speech acoustics may be achieved if the ratio between the direct sound energy and the reverberant energy is high. Also, if the space is sufficiently large enough so as to require an integrated speech reinforcement system, highly directional loudspeakers may be employed to distribute sound to the audience with a minimum excitation of the reverberant room. Typical reverberation times for auditoria range from 1.2 to 1.5 seconds. Because the reverberation time measured in an auditorium is related to the amount of sound-absorbing material present, it is influenced by the number of people sitting in the audience. To maintain a certain degree of reverberation time invariability with respect to audience size, it is important to choose upholstered seats; upholstered seats most closely resemble the absorption characteristics of seated audience members.

SOLVED PROBLEMS

1.1 For an empty assembly hall of size 20 × 15 × 10 cubic meter with absorption coefficient 0.106. Calculate reverberation time.

Solution:

Given:

(i) Size of the room = 20 × 15 × 10

$= 3000\ m^3$

(ii) a = 0.106

Formula $$T = \frac{0.161V}{\sum aS} = \frac{0.161V}{aS}$$

Here S = Total surface area of the hall is given by,

$S = 2(20 \times 15 + 15 \times 10 + 20 \times 10)$

$= 1300\ m^2$

$$\therefore \text{Reverberation time } T = \frac{(0.161 \times 3000)}{(0.106 \times 1300)} = \frac{483}{137.8} = 3.50\,\text{s}$$

∴ Reverberation time = 3.50 s

1.2 A hall of volume 5500 m^3 is found to have a reverberation time of 2.3 seconds. The sound absorbing surface of the hall has an area of 750 m^2. Calculate the average absorption coefficient.

Solution:

Given: $V = 5500\ m^3$, $T = 2.3$ s, $S = 750\ m^2$

Let absorption coefficient be ‘a’

∴ Using Sabine's formula

$$T = \frac{0.161\,V}{\sum aS}$$

$$a = \frac{0.161\,V}{TS} = \frac{0.161 \times 5500}{2.3 \times 750} = 0.513.$$

1.3 For an empty hall of size 20 × 12 × 12 cubic meter, the reverberation time is 2.5 seconds Calculate the average absorption co-efficient of the hall. What area of the floor should be covered by carpet so as to reduce the reverberation time to 2 seconds. Given that absorption co-efficient of carpet is 0.5.

Solution:

(a) Reverberation time

$$T_1 = \frac{0.161\,V}{aS} \qquad \text{... (1)}$$

$$\therefore\ aS = \frac{0.161\,V}{T_1} = \frac{0.161 \times 20 \times 12 \times 12}{2.5} = 185.47$$

Now total surface area of the hall,

$$S = 2\,(20 \times 12 + 12 \times 12 + 20 \times 12)$$

$$= 1248\ m^2$$

$$\therefore\ a = \frac{185.47}{1248} = 0.149$$

(b) By using the carpet of surface area S_1 whose absorption coefficient is 0.5, the reverberation time is reduced to 2 seconds.

∴ Let $T_2 = 2$ seconds

Carpet surface = S_1

Co-efficient of absorption of carpet $a_c = 0.5$

∴ Writing Sabine's formula

$$T_2 = \frac{0.161V}{aS - aS_1 + a_cS_1} \qquad \text{... (2)}$$

[Here Total surface area = S, now if carpet is used of area S_1, the area covered by the material with co-efficient of absorption a is, $a\,(S - S_1) = aS - aS_1$]

From Equation (1),

$$\frac{1}{T_1} = \frac{aS}{0.161\,V} \qquad \text{... (3)}$$

From Equation (2),

$$\frac{1}{T_2} = \frac{aS + a_cS_1 - aS_1}{0.161\,V} \qquad \text{... (4)}$$

$$\therefore\ \frac{1}{T_2} - \frac{1}{T_1} = \frac{1}{0.161\,V}\,[a_c\,S_1 - aS_1]$$

$$\therefore \frac{1}{T_2} - \frac{1}{T_1} = \frac{a_c S_1 - aS_1}{0.161\,V} = \frac{S_1(a_c - a)}{0.161\,V}$$

$$\therefore \qquad S_1 = \left(\frac{1}{T_2} - \frac{1}{T_1}\right)\frac{0.161\,V}{(a_c - a)}$$

$$\therefore \qquad S_1 = \frac{0.161V}{(a_c - a)}\left[\frac{1}{T_2} - \frac{1}{T_1}\right] \qquad \ldots (5)$$

$$\therefore \qquad S_1 = \frac{0.161 \times 20 \times 12 \times 12}{0.5 - 0.149}\left[\frac{1}{2} - \frac{1}{2.5}\right] = 132.1 \text{ m}^2$$

∴ Carpet area required to reduce reverberation time up to 2 seconds. is 132.1 m^2.

1.4 A hall with dimensions 16 × 10 × 10 cubic meter is found to have reverberation time 4 seconds. What is the total absorbing power of all the surfaces in the hall?

Solution:

V = Volume of a hall = 16 × 10 × 10 = 1600 m^3

T = Reverberation time = 4 seconds.

$$\therefore \ T = \frac{0.161V}{\sum aS}$$

$$\sum aS = \frac{0.161V}{T} = \frac{0.161 \times 1600}{4} = 64.4 \text{ sabins.}$$

UNSOLVED PROBLEMS

1. A classroom with a volume of 1600 m^3 has a reverberation time of 2 seconds. Find the total absorbing power of all the surface in the room. (**Ans.:** 128.8 sabins)
2. A cinema hall has a volume of 7500 m^3. It is required to have reverberation time of 1.4 seconds, what should be the total absorption in the hall? (**Ans.:** 862.5 OWU)
3. The volume of the room is 1200 m^3. The wall area is 220 m^2, the floor area is 120 m^2, ceiling area 120 m^2. The average sound absorption coefficient – (i) for wall is 0.03, (ii) for ceiling 0.8 and (iii) for floor is 0.06. Calculate the average sound absorption coefficient and reverberation time. (**Ans.:** 0.24 and T = 1.76 s)
4. For an empty assembly hall of size 20 × 15 × 10 m^3, the reverberation time is 3.5 seconds. Calculate the average absorption co-efficient of the hall. What area of the wall should be covered by the curtain so as to reduce the reverberation time to 2.5 seconds? Given the absorption co-efficient of the curtain cloth is 0.5. (**Ans.:** 0.106, 140.12 m^2)
5. A classroom has dimensions 20 × 15 × 5 m^3. The reverberation time is 3.5 seconds. Calculate average absorption co-efficient. (**Ans.:** 0.07)
6. The reverberation time is found to be 1.5 seconds for an empty hall and it is found to be 1 second when a curtain of 20 m^2 is suspended at the center of the hall. If the dimensions of the hall are 10 × 8 × 6 m^3, calculate co-efficient of absorption of curtain. (**Ans.:** 0.64)

QUESTIONS

1. What do you mean by reverberation and reverberation time? What are the causes of reverberation and how will you minimise it?
2. State Sabine's formula for reverberation time of a hall. State its significance.
3. What is absorption coefficient of a material? Obtain the relation between absorption coefficient and time of reverberation.
4. State the factors affecting the acoustics of building.
5. What are the features of acoustically good auditorium?
6. Write short note on Acoustics of Buildings.

MULTIPLE CHOICE QUESTIONS

1. The ideal absorber of the sound: ____________.
   (a) open window (b) carpet
   (c) heavy curtain (d) perforated cellulose fiber files
2. Reverberation time is: ____________.
   (a) directly proportional to volume (b) inversely proportional to volume
   (c) equal to volume (d) none of the above
3. The preferred one for acoustically correct auditorium: ____________.
   (a) parallel walls (b) splayed walls
   (c) curved walls (d) white wall
4. The time gap between the initial direct note and the reflected note up to a minimum audibility level is ____________.
   (a) deflection time (b) absorption time
   (c) reverberation time (d) echo time
5. The absorption coefficient is measured in ____________.
   (a) closed window unit (b) open window unit
   (c) open door unit (d) none of these
6. Echelon effect is produced by ____________.
   (a) floors (b) ceiling
   (c) curved surfaces (d) staircase
7. Use of absorbents ____________ the reverberation time.
   (a) increases (b) decreases
   (c) have no effect on (d) can increase or decrease
8. Reverberation of sound in a hall is ____________.
   (a) a desirable effect in a controlled way
   (b) undesirable effect
   (c) sometimes desirable and sometimes undesirable
   (d) essential evil
9. Reverberation time is given by ____________.
   (a) Sabine (b) Weber-Fechner law
   (c) Weber's law (d) Sabine-Fechner law

10. For a given hall absorption coefficient is 0.2 and volume 1000 m^3 and absorbing area 4200 m^2. The reverberation time is ____________.
    (a) 2.08 s (b) 2.8 s
    (c) 2.008 s (d) 2.18 s
11. The ideal absorber of the sound: ____________.
    (a) open window (b) carpet
    (c) heavy curtain (d) perforated cellulose fiber files
12. To get good sound effect inside a hall ____________.
    (a) the reverberation time has to be as large as possible.
    (b) the reverberation time has to be zero.
    (c) the hall should not have any absorbing material.
    (d) the reverberation time has to be optimum.
13. Optimum reverberation time for music is ____________.
    (a) 0.5 to 1 seconds (b) 0 to 1 seconds
    (c) 1 to 2 seconds (d) above 5 seconds
14. Which one of the following has minimum absorption coefficient?
    (a) glass (b) felt
    (c) open windows (d) wooden floor
15. The walls of a halls built for music concerns should ____________.
    (a) amplify sound (b) reflect sound
    (c) transmit sound (d) absorb sound
16. The time of reverberation of a hall can be reduced by using ____________.
    (a) reflectors (b) absorbers
    (c) domes (d) arch
17. For a uniform distribution of sound intensity is it better to have ____________.
    (a) parabolic reflector (b) concave reflector
    (c) spherical reflector (d) cylindrical reflector
18. The walls of hall built for music concerns should ____________.
    (a) amplify sound (b) reflect sound
    (c) transmit sound (d) absorb sound
19. A cinema hall has a volume of 700 m^3 and the total absorption in the hall is 700 O.W.U. The time of reverberation should be ____________.
    (a) 0.165 s (b) 1.65 s
    (c) 0.49 s (d) 4.9 s
20. The Sabine is the unit of ____________.
    (a) energy (b) reverberation time
    (c) absorption of a hall (d) reflection by a wall

[**Ans.:** 1. (a); 2. (a); 3. (b); 4. (c); 5. (b); 6. (d); 7. (b); 8. (a); 9. (a); 10. (a); 11. (a); 12. (d); 13. (c); 14. (a); 15. (d); 16. (c); 17. (a); 18. (d); 19. (a); 20. (c)]