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4

STUDIO ACOUSTICS

4.1 INTRODUCTION

Previously you have studied about the fundamentals of sound technology. Now, let us learn about the studio acoustics.

Sound production not only depends upon the quality(notes) of the sound generated from a source like human vocal-chord or an electro-mechanical speaker, but it depends upon the medium through or from which is comes after reflection, refraction, diffraction, absorption or interference. Thus, acoustics plays a vital role in sound production.

In this lesson, you will learn about the basic acoustic principles and construction techniques for consideration, while designing sound production facility. Acoustics pertains to the art of designing that necessitates intuition, experience and common sense. This will include understanding reflection, refraction, reverberation, noise level, materials used and transmission techniques.

4.2 OBJECTIVES

After reading this lesson, the learner will be able to :

- explain reflection;
- identify laws of reflection;
- analyze reverberation, sound isolation and noise level;
- enumerate basics of psychoacoustics.

4.3 MEANING OF ACOUSTICS

Acoustics can be defined as a science dealing with the production, effects and transmission of sound waves through different media including reflection, refraction, diffraction, absorption and interference. It also includes consideration about characteristics of auditoriums, theatre and studios along with their design.

4.3.1 Identifying need of Acoustic treatments

There are various situations needing enhacing the quality of sound in an enclosed space, tackling the interference problems etc. which require acoustic treatment to be done. Important role of studio acoustics (SA) is to identify such problems first. Like:

(a) While clapping your hands if a fluttering sound is heard because of sounds bouncing back and forth from hard parallel walls then this needs acoustic treatment.

(b) If the studio is made up like concrete block basement or garage, so you hear too much room reverberation.

(c) If the studio is too small

(d) If you hear, outside voices in the recordings.

(e) If bass guitar amps & monitor speakers sound booms

(f) If you hear a lot of leakage in mic signals.

All these would need attention to be paid to the acoustic aspects to improve the quality of sound

4.3.2 Factors governing studio and control room acoustics

Studio and control room acoustics, play a very important role while recording any musical program. Irrespective of which type of studio facility is being designed, built and being used, there are various factors, which should be addressed, in order to achieve the best possible acoustic results. Such as:

1. **Acoustic isolation**- appropriate isolation techniques are necessary to incorporate into their design, in order to keep external noises to the minimum. Whether that noise is transmitted through the medium of air or though solids special construction techniques are often required to dampen these external sounds. The goal here is to build a studio wall, floor, ceiling, window or door out of thickest and most dense sound absorbant material available to improve sound isolation

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2. **Symmetry in control room and monitoring design**-There should be symmetrical reflections on all axes within the design of a control room or single room project of a studio. The center and acoustic imaging is best when the listener, speakers, walls and other acoustical boundaries are symmetrically centered around the listener's position . In a rectangular room, the best low end response can be obtained by orienting the console and loudspeakers into the room's long dimension. Placing the listening environment symmetrically in a corner, is another example of how the left/right imagery can be improved over an off center placement.

3. **Frequency balance:**The frequency components of a room shouldn't adversely affect the acoustic balance of instruments and speakers. The acoustic environment shouldn't alter the sound quality of the original or recorded performance**.** Room should exhibit a relatively flat frequency response, over the entire audio range, without adding its own sound coloration. The most common way to control the tonal character of a room, is to use materials and design techniques that govern the acoustical reflection and absorption factors.

4. **Reflection:** Reflection is the change in direction of a wave front at an interface between two different media so that the wave front returns into the medium from which it originated. Common examples include the reflection of light, sound and water waves.

DO YOU KNOW?

The *law of reflection* says that, for spectacular reflection, the angle at which the wave is incident on the surface equals the angle at which it is reflected (both values measured from the normal N). Light is known to behave in a very predictable manner. If a ray of light could be observed approaching and reflecting off a flat mirror, then the behavior of the light as it reflects would follow a predictable *law* known as the **law of reflection**. The diagram below (Fig. 4.1) illustrates the law of reflection.

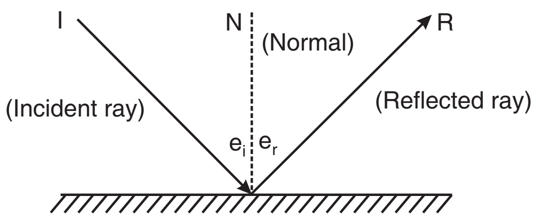

Fig. 4.1: Law of reflection

Reflection of sound – just as a mirror reflects, light, when sound waves, radiating out from a source, strike a rigid obstacle, the angle of reflection of the sound waves is same as the angle of incident, if no absorption occurs)

5. **Absorption:** Absorption occurs, when only a portion of the incident acoustic energy is reflected back from a material's surface. The absorption of acoustical energy is inverse of reflection. Whenever sound strikes a material, the amount of acoustic energy that absorbed, relative to the amount that's reflected, can be expressed as a simple ratio known as the material's absorption coefficient. You have learnt about absorption coefficient in first chapter on Introduction to sound.

6. **Reverberation:** A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation. Reflection of sound waves of the surfaces can lead to **reverberation**. A reverberation often occurs in a small room with height, width, and length dimensions of approximately 17 meters or less. Reflection of sound waves also leads to **echoes**.

   Like any wave, a sound wave doesn't just *stop* when it reaches the end of the medium or when it encounters an obstacle in its path. Rather, a sound wave will undergo certain behaviors when it encounters the end of the medium or an obstacle. Possible behaviors include reflection off the obstacle, diffraction around the obstacle, and transmission (accompanied by refraction) into the obstacle or new media.

DO YOU KNOW?

Why the magical 17 meters? The affect of a particular sound wave upon the brain endures for more than a tiny fraction of a second; the human brain keeps a sound in memory for up to 0.1 seconds. If a reflected sound wave reaches the ear within 0.1 seconds of the initial sound, then it seems to the person that the sound is *prolonged*. The reception of multiple reflections off the walls and ceilings, within 0.1 seconds of each other, causes reverberations - the prolonging of a sound. Since sound waves travel at about 340 m/s at room temperature, it will take approximately 0.1 s for a sound to travel the length of a 17 meter room and back, thus causing a reverberation ($t = v/d = (340\ m/s)/(34\ m) = 0.1s$). This is why reverberations are common in rooms with dimensions of approximately 17 meters or less.

7. **Cost factors:** Designing acoustical studios can be a costly affair. Studio designers and construction teams spend a lot to create plush décor that has been acoustically tuned to fit the needs of both owners and budget minded production facilities , however the same can be done in cost effective ways also keeping in view the production needs and future prospects of growth.

In addition to above some related factors are explained hereunder.

4.4 PROPAGATION OF SOUND

Propagation of sound through the air is in the form of longitudinal waves. The speed of sound depend on the properties of air and not on the frequency or amplitude of sound waves. As in case of light same lwaw of reflection applies to sound also i.e., angle of incident is equal to the angle of reflection where measured about the normal.

INTEXT QUESTIONS 4.1

1. Reflection is ....?

   (a) Change in the direction of a wave front

   (b) Change in sight

   (c) both (a) and (b)

   (d) none of these

2. In acoustics, reflection causes .... ?

   (a) echoes (b) reflection

   (c) wave (d) light

3. The human brain keeps a sound in memory for up to .... seconds.

   (a) 0.2 Seconds (b) 0.1 Seconds

   (c) 1 Seconds (d) None of these

4. Reflection of sound waves also leads to ....

   (a) Echoes (b) Clear Sound

   (c) Bad Sound (d) A and B

5. Light is known to behave in a very .... manner

   (a) predictable (b) unpredictable

   (c) hypothetical (d) straight

4.5 REFRACTION

The turning or bending of any wave, such as a light or sound wave, when it passes from one medium into another of different optical density, is called Refraction.

Refraction is the change in direction of a wave due to a change in the medium of transmission. The phenomena is governed by the laws of conservation of energy and momentum. When medium changes, the phase velocity of the sound also changes but frequency remains unaffected, especially at incident angles other than 90° or 0°. This phenomena is observed in all the waves like sound and water. As per Snell's law for a given pair of media and a wave with a single frequency, the ratio of sine's of the angle of incident Q_1 and the angle of refraction Q_2 is equal to the ratio of phase velocities V_1/V_2 in the two media to the opposite ratio of the indices of refraction (n_2/n_1)

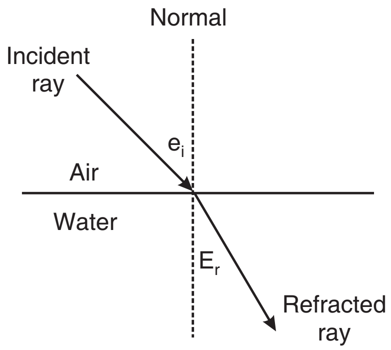

Fig. 4.2: Law of Refraction

As shown in the diagram (Fig 4.2) above, a normal line is drawn to the surface at the point of incidence. This line is always drawn perpendicular to the boundary. The angle that the incident ray makes with the normal line is referred to as the **angle of incidence**. Similarly, the angle that the refracted ray makes with the normal line is referred to as the **angle of refraction**. The angle of incidence and angle of refraction is denoted by the following symbols:

θ_1 = angle of incidence

θ_2 = angle of refraction

The amount of bending that a light ray experience, can be expressed in terms of the angle of refraction. A ray of light may approach the boundary of a medium at an angle of incidence of 45-degrees and bend towards the normal. If the medium into which it enters causes a small amount of refraction, then the angle of refraction might be of a value of about 42-degrees. On the other hand if the medium into which the light enters causes a large amount of refraction, the angle of refraction might be 22-degrees. (These values are merely arbitrarily chosen values to illustrate a point.) The diagram below depicts a ray of light approaching three different boundaries, at an angle of incidence of 45-degrees. The refractive medium is different in each case, causing different amounts of refraction. The angles of refraction are shown on the diagram. (Fig. 4.3) below.

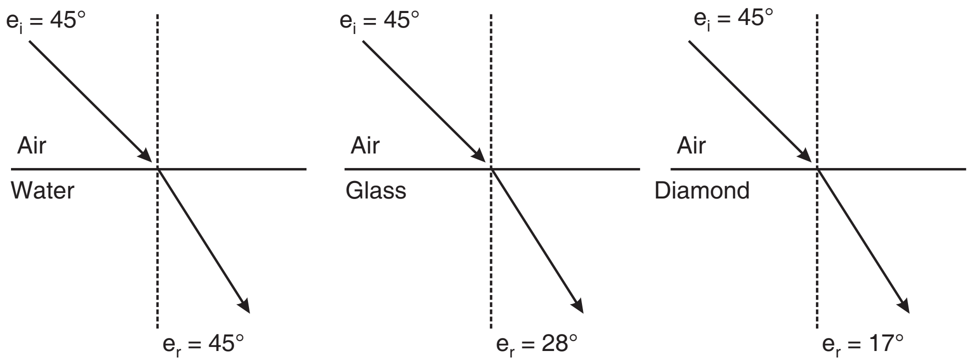

Fig. 4.3: Different angles of Refraction for different mediam

Of the three boundaries in the diagram, the light ray refracts the most at the air-diamond boundary. This is evident by the fact that the difference between the angle of incidence and the angle of refraction is greatest for the air-diamond boundary.

INTEXT QUESTIONS 4.2

1. Refraction is the ....?
   (a) change in direction of a wave
   (b) change in direction
   (c) change in nature of work
   (d) all of these
2. Refraction is essentially a .... phenomenon
   (a) surface (b) normal
   (c) usual (d) transmission
3. In Refraction its frequency remains ....
   (a) constant (b) normal
   (c) abnormal (d) speedy
4. The speed of a sound wave in air depends on the ....
   (a) Temperature (b) clouds
   (c) rains (d) b and c
5. The angle of refraction is dependent upon the ....
   (a) Speeds of light (b) speed of air
   (c) speed of volume (d) speed

4.6 NOISE LEVEL

Noise is the unwanted sound and in many applications noise reduction is a must. Noise can cause of loss of hearing power, interfere with sleep, speech, cause discomfort.. The importance of noise issue could be well understood by looking at regulations that have been passed by governments to restrict noise production or control noise pollution in society.

Active Noise control

Passive noise control refers to those methods that aim to suppress the sound by modifying the environment closer to the source. Since no input power is required in such methods, Passive noise control is often cheaper than active control, however the performance is limited to mid and high frequencies. Active control works well for low frequencies hence, the combination of two methods may be utilized for broadband noise reduction as shown below Fig. 4.4.

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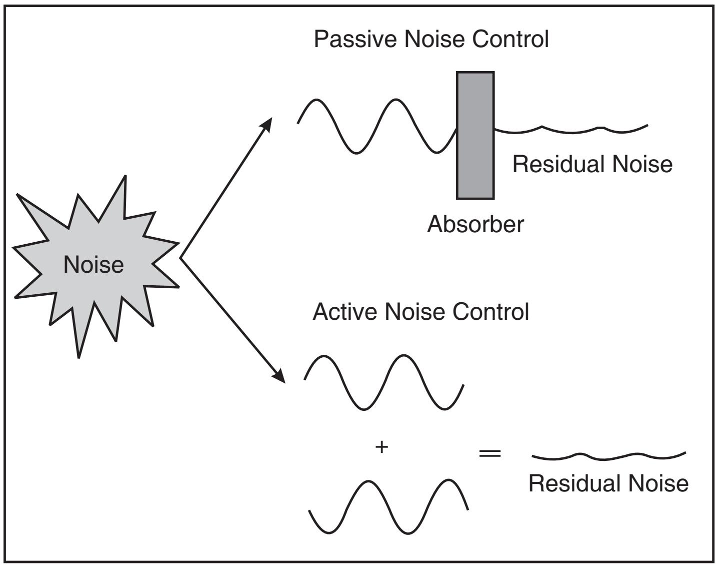

Fig. 4.4: Passive Noise Control and Active Noise Control

Sound waves striking an arbitrary surface are reflected, transmitted or absorbed; the amount of energy going into reflection, transmission or absorption depends on acoustic properties of the surface. The reflected sound may be almost completely redirected by large flat surfaces or scattered by a diffused surface. When a considerable amount of the reflected sound is spatially and temporally scattered, this status is called a diffuse reflection, and the surface involved is often termed a diffuser. The absorbed sound may either be transmitted or dissipated. A simple schematic of surface-wave interactions is shown in Fig. 4.5.

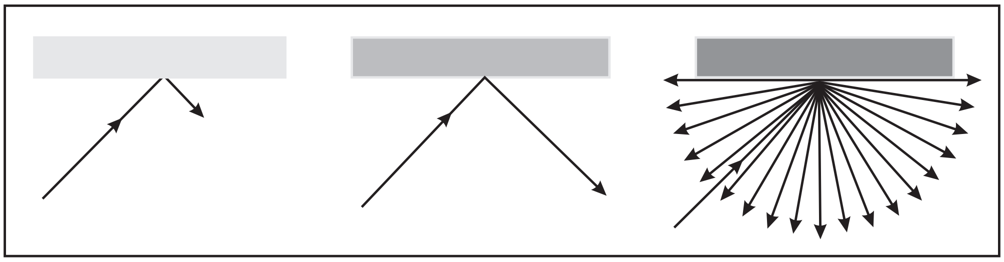

Fig. 4.5: Surface wave interaction

Sound energy is dissipated by simultaneous actions of viscous and thermal mechanisms. Sound absorbers are used to dissipate sound energy and to minimize its reflection.

Furnishing curtain against the walls, absorb high frequency better than lower areas. When curtains are placed further away from walls, lower frequency is also absorbed. The amount of sound absorbed will depend upon the type of the material used for certain fiberglass (Rockwool) has the highest absorbing capacity. Fiberglass is used with brick, stone, concrete etc. due to its sharp edges. Timber, steel reflects higher frequencies but absorbs certain percentage of lower frequencies, balance of the lower frequency pass through the wall. Bass frequencies are the most difficult to absorb.

The 1/4 wavelength rule: Absorbent material (soft or fiberglass) must be kept at 1/4 wavelength of the lowest frequency to be absorbed. This helps to absorb all higher frequencies. This may make the room seem smaller but it will be calmer and relaxing. Ref. Fig 4.6 below.

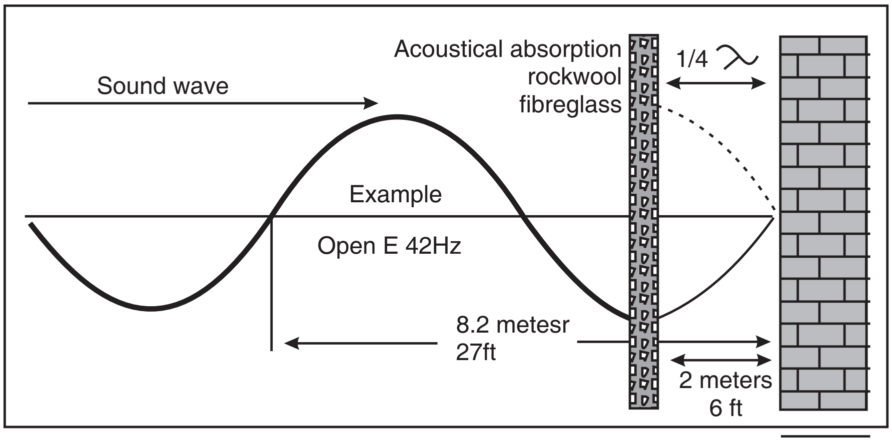

Fig. 4.6: Placement of sound absorbent material

4.6.1 Making a quieter studio

An ideal noise level in a studio should be 23-28 dB.As measured on SPL meter. Following tips will be useful to keep away the noise from studio recordings.

1. All appliances, air conditions and telephones etc. should be switched off while recording.
2. All doors and windows of the studio, if any should be closed or cover them with thick plywood.
3. Objects that can rattle or buzz should be removed.
4. There should be carpet or several layers of plywood on the floor above studio. Moreover, there should be an insulation in the air space between studio ceiling and the floor above.
5. Microphones should be placed, close to the instruments and use directional microphones. This will reduce noise picked up by the microphones from other directions/ sources.

INTEXT QUESTIONS 4.3

1. Modifying and canceling sound field of electro-acoustical approaches are called ....

   (a) active noise control (b) passive noise control

   (c) negative voice control (d) mix noise control

2. Wool (fiberglass) has the .... absorption capacity

   (a) highest (b) lowest

   (c) medium (d) none of these

3. Passive noise control is often .... than active control

   (a) cheaper (b) higher

   (c) medium (d) within cost

4. The amount of sound energy absorbed depends on type of .... weight and pleating width

   (a) material (b) glass

   (c) energy (d) none of these

4.7.1 Sound Transmission

Sound is a travelling pressure wave that can be transmitted through air, liquids, or solids and is sensed by the human ear. The wave is a vibration or fluctuation in pressure and can vary in amplitude (i.e. Loudness or volume) and frequency (i.e. pitch). Sound volume is measured indecibels, while the frequency of sound is measured in hertz. The frequency and amplitude of sound can change as the wave travels through different mediums. For example, the loudness of a sound is reduced as it travels from the air through a wall of concrete

Acoustic transmission in building design refers to a number of processes/ways by which sound can be transferred from one part of a building to another. Typically these are:

1. **Airborne transmission** - To isolate one room from the other, so that sound from other rooms is not heard in the adjacent room, structural isolation is considered at the time of design stage of the building, especially in the recording studios or the highly sensitive areas. A tighten sealed door also helps in reduction of such air borne sound. Heavy dividing walls, help in effective reduction of airborne sound transmission better than a light one.

2. **Impact transmission** - A noise source in one room, results from an impact of an object onto a separating surface, such as a floor and transmits the sound to an adjacent room. A typical example would be the sound of footsteps in a room being heard in a room below. Acoustic control measures usually include attempts to isolate the source of the impact, or cushioning it. For example, carpets will perform significantly better than hard floors.

3. **Flanking transmission** - A more complex form of noise transmission, where the resultant vibrations from a noise source are transmitted to other rooms of the building usually by elements of structure within the area.

4. **E building**. For example, in a steel framed building, once the frame itself is set into motion the effective transmission by vibration can be pronounced.

Sound Absorption

Sound absorption is the process by which we can reduce the reflection of the sound energy by the surfaces. As we have already seen the absorption phenomenon of sound wave from which it is clear that when sound wave strikes the acoustically treated surface some of the sound wave penetrates the acoustic material covering the wall and portion of that sound energy is retained by the absorbing material. This absorbed sound energy is converted into heat energy thereby preventing any retransmission or reflection of sound wave from the surface. The absorbing material will be selected on the basis of frequency distribution of noise and application of the studio. Different absorbers show different absorption characteristics which are non uniform over the complete frequency spectrum.

For achieving optimum R/T characteristics combination of acoustic absorbers is used in the studio. Every material has some absorptive qualities. This is described by its coefficient of absorption, a number between 0 and 1, the value 0 corresponds to totally reflective and 1 corresponds to an open window . These numbers can be used to compare materials and to predict the results of treatment. Some of the commonly used absorbers are:

(i) ***Porous Materials:*** Porous materials are used for the absorption of Mid and High Frequencies. Mineral wool, glass wool are members of this class. These materials are very good absorber and are most effective in *Mid and High Frequencies.* These absorbers are used with the covering material which acts as a face of such absorbers. Fabric used as a Carpet and Curtain also act as absorber for Mid and High Frequencies.

(ii) ***Fibrous Materials:*** Insulation boards, perforated tiles fall in fibrous material category. The tiny holes in the fibrous material acts as a trap which are responsible for the absorption of sound and dissipation of the sound energy. The Absorption of these materials increases with increase in the softness of the material. These materials have very poor absorption on low frequencies.

(iii) ***Panel/ Resonant Absorbers:*** Panel absorbers are thin wooden ply/ veneers with an air cavity behind. This is generally used as *Low Frequency Absorber (LFA).*

4.8 BASICS OF PSYCHOACOUSTICS

4.8.1 Psychoacoustics – Threshold of hearing and pain

The intensity level of a loud sound, which gives pain to the ear, is usually between 115 and 140 dB (see graph). For some listeners, with hyperacusis, these levels may be much lower.

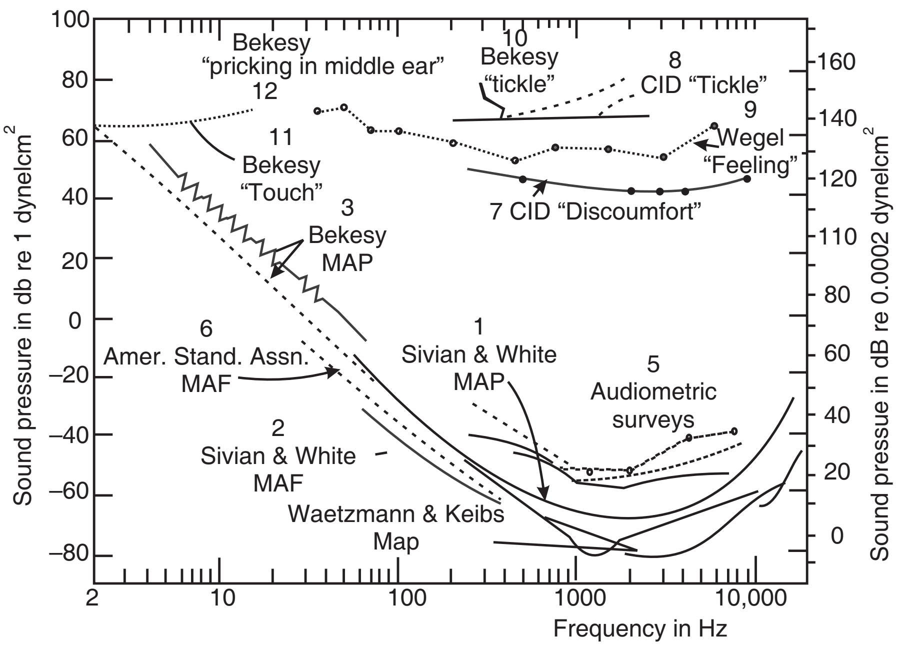

Fig. 4.7

The **threshold of hearing** is the Sound pressure level SPL of 20 µPa (micropascals) = 2×10^{-5} pascals (Pa). This low threshold of amplitude (strength or sound pressure level) is frequency dependent. See the frequency curve in Fig. 2 below

The **absolute threshold of hearing** (ATH) is the minimum amplitude (level or strength) of a pure tone that the average ear with normal hearing can hear in a noiseless environment.

The **threshold of pain** is the SPL beyond which sound becomes unbearable for a human listener. This threshold varies only slightly with frequency. Prolonged exposure to sound pressure levels in excess of the threshold of pain can cause physical damage, potentially leading to hearing impairment.

Different values for the threshold of pain:

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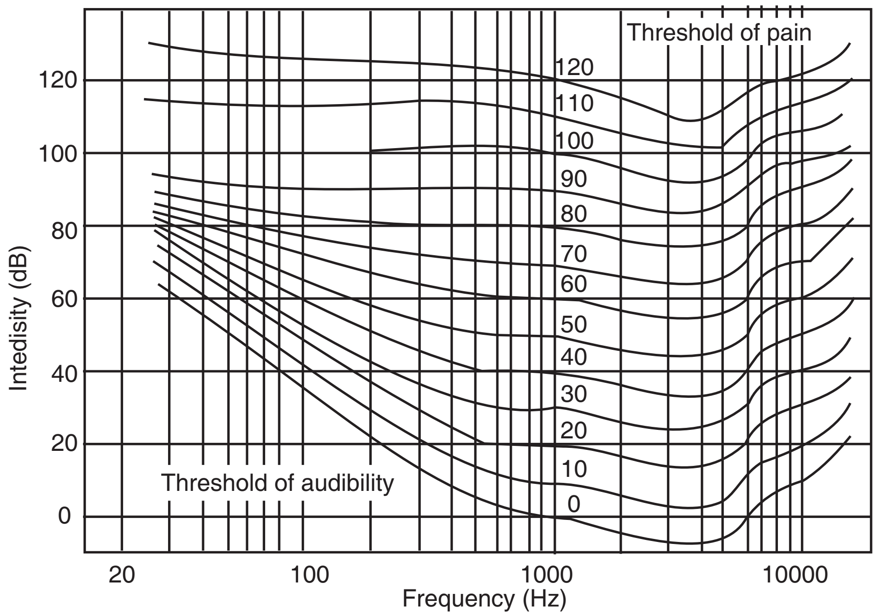

Fig. 4.7: Threshold of audibility

Threshold of pain

SPL	Sound pressure
120 dBSPL	20 Pa
130 dBSPL	63 Pa
134 dBSPL	100 Pa
137.5 dBSPL	150 Pa
140 dBSPL	200 Pa

The threshold of haring is the minimum sensitivity of the ear and lies with 1 kHz to 5 kHz. It is frequency dependent (see curve in Fig. 4.5) where lowest curve is the absolute threshold of hearing and the highest curve in the threshold of pain. Any part of the audio signal whose amplitude is below the ATM level, can be removed without affecting any change to the signal.

INTEXT QUESTIONS 4.4

1. Sound is a travelling pressure wave that can be transmitted through air, liquids, or solids and is sensed by the human ....?

   (a) ear (b) eyes

   (c) hands (d) tongue

2. The lntensity level of a loud sound which gives pain to the ear, usually between ....

   (a) 115 and 140 dB (b) 110 & 120 dB

   (c) 90 & 95 dB (d) none of these

3. The threshold of hearing is the .... level SPL

   (a) sound pressure (b) water Pressure

   (c) air Pressure (d) wall Pressure

4. The threshold of pain is the SPL beyond which sound becomes .... for a human listener

   (a) unbearable (b) easily bearable

   (c) adjustable (d) bearable

4.8 WHAT HAVE YOU LEARNT

In this lesson you learnt about the meaning of acoustics and the factors governing studio and control room acoustics factors which govern the studio acoustics include acoustic isolation symmetry in control room and monitoring design, frequency balance, reflection absorption, reverberation and cost implications etc. In addition to this, noise control and psych acoustics were also discussed.

4.9 TERMINAL QUESTIONS

1. Define acoustics. Discuss why on acoustic treatment is required in a studio setup?

2. Explain the various factors governing studio and control room acoustics.

3. Write short note on

   (i) Psychoacoustics

   (ii) Refraction

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4.10 ANSWERS TO INTEXT QUESTIONS

4.1

1. (a) 2. (a) 3. (b) 4. (a) 5. (a)

4.2

1. (a) 2. (a) 3. (a) 4. (a) 5. (a)

4.3

1. (a) 2. (a) 3. (a) 4. (a)

4.4.

1. (a) 2. (a) 3. (a) 4. (a)