CHAPTER

7

Noise Pollution and Control

We love to hear music. The sound which produces pleasant effect on our ears is the musical sound. Noise, on the other hand, is the sound with no musical quality. A sound is pleasant when it is soft and rhythmic but noisy when loud and repeated randomly. Lots of unwanted sounds are nowadays dumped continuously into the environment, creating noise pollution through human activities. The basic difference between noise pollution and other kinds of pollution is that it does not leave any residue in the environment, although it has high degree of adverse effect on physical and mental health of human beings as well as on many other living organisms. Considering such effects, proper care must be taken to protect the environment, otherwise a day might come when mentally and physically imbalanced people will inhabit the beautiful planet earth.

7.1 SOUND

There are two ways of energy transfer:

(*i*) Through transportation of matter: A stone is thrown into water, energy of stone gets transferred to water.

(*ii*) Without transportation of matter, *i.e.*, through waves: Wave can be defined as a kind of disturbance through which energy is transported from one place to another, through vibration of the medium without transportation of matter. A wave is a periodic disturbance or a deformation of the medium it takes place in.

For example, sound waves are pressure variations which deform the air or other medium through which they travel.

A wave can be classified as:

(*i*) **Elastic or mechanical waves:** The waves that require material media for their propagation are called elastic wave or mechanical wave. For example, sound waves in air.

(*ii*) **Electromagnetic waves:** The waves that do not require any material media are known as electromagnetic waves. For example, light waves, x-ray, γ-ray, etc.

The waves so far discussed can be: (*a*) transverse waves (*b*) longitudinal waves.

(*a*) **Transverse waves:** The waves in which each particle of the medium executes vibrations about its mean position and is perpendicular to the direction of the waves are called transverse waves. For example, the waves generated in a pond when a stone is thrown, all electromagnetic waves, stretched string of sitar, violin, etc. (Fig. 7.1(*a*))

(*b*) **Longitudinal waves:** The waves in which each particle of the medium executes vibrations about its mean position, in the direction of the propagation of the wave, are called longitudinal waves. For example, sound waves in air, sound waves inside water (Fig. 7.1 (*b*)).

Longitudinal waves can also be defined as the waves in which the medium particles have periodic change in displacement and pressure in the direction in which they travel.

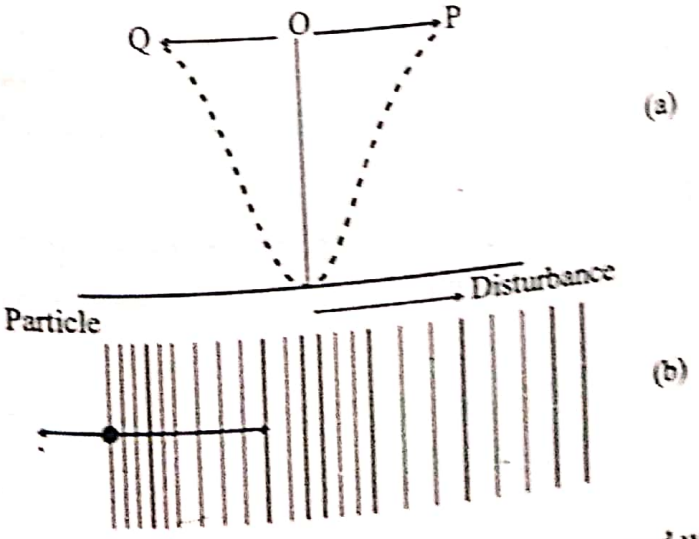


Fig. 7.1. Disturbance of tuning fork producing sound waves

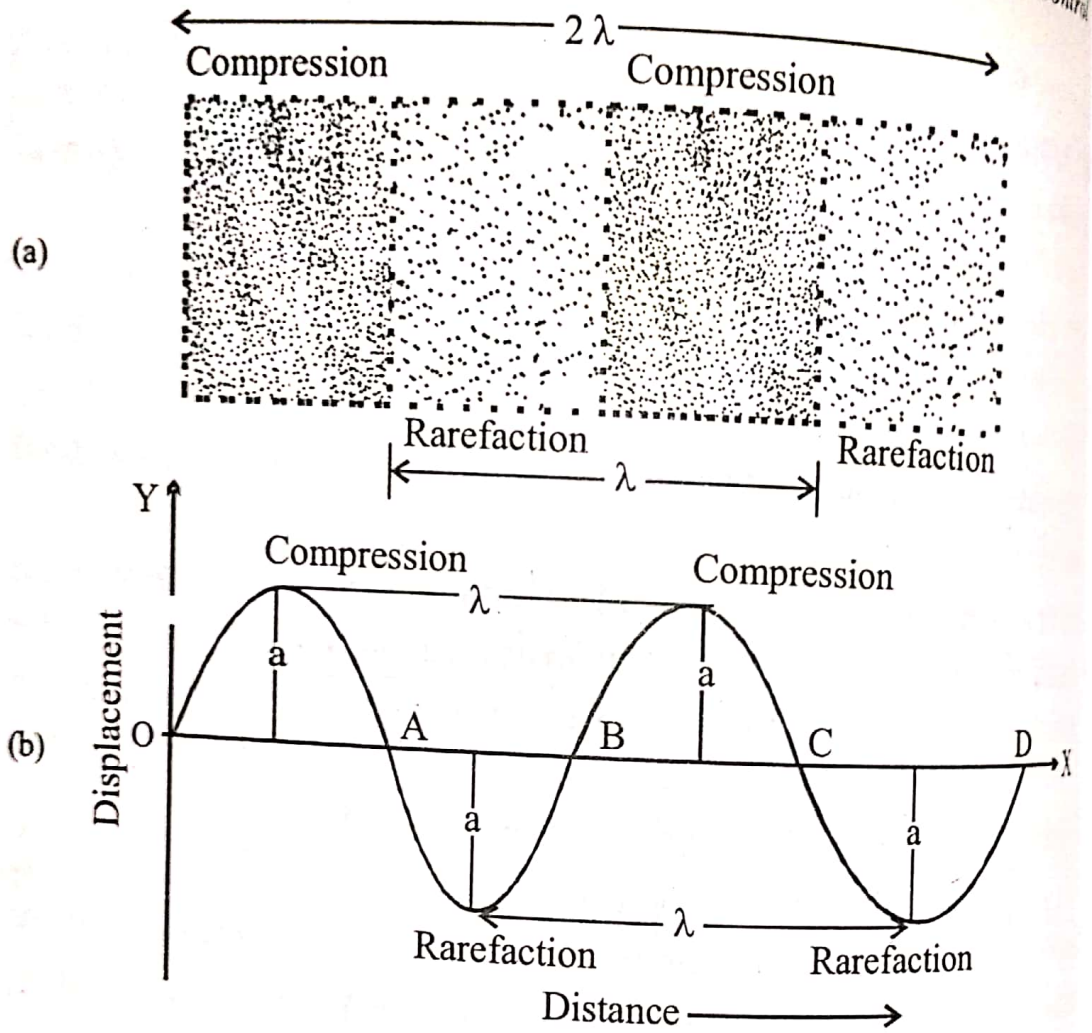


Fig. 7.2. Graphical representation of a wave

In a longitudinal wave, if the particles of the medium vibrate horizontally (the direction of movement of the tuning fork), then the disturbance also travels horizontally (Fig. 7.1(*b*)). Again this wave travels in the form of compression and rarefaction (Fig.7.2 (*a*)).

A compression is the region or a space of the medium, in which the particles come close to a distance less than the normal distance between them.

A rarefaction is the region or a space of the medium, in which the particles get apart to a distance greater than the normal distance between them.

Frequency: The number of waves passing through a point in one second or number of oscillations per second is called frequency.

SI unit is hertz or cycles/second.

The symbol used is neu (ν).

A full or complete wave is represented in Fig. 7.3.

Thus, in a full or complete wave, there will be one crest (or compression) and one trough (or rarefaction).

Frequency ν implies that there are ν crests or compressions and ν troughs or rarefactions.

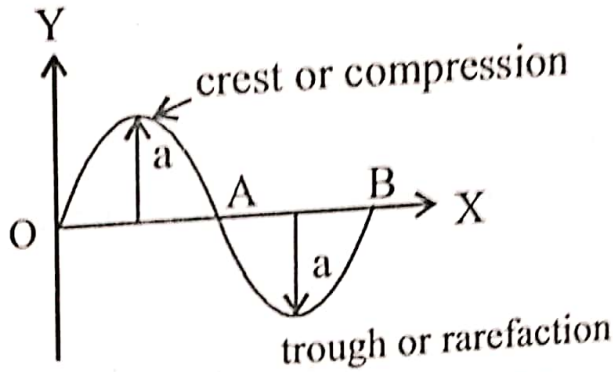


Fig. 7.3. Graphical representation of a full wave

Time period: The time taken by one wave to pass through a point is called the time period of the wave, *i.e*,. $T = 1/\nu$. The unit is second(s).

Amplitude: The maximum displacement of a media particle on either side of its mean (rest) position is called the amplitude of the wave. Its S.I unit is meter (m). It is represented by the letter '*a*'.

Wavelength: The distance covered by the wave in one time period is called the wavelength. Time period is the time taken by one wave to pass through a point, that is, in that time it has covered a distance OA (Fig. 7.2 (*b*)). OA may vary from wave to wave and with the increase in amplitude, OA will be shortened.

The wavelength can also be defined as the distance between two consecutive particles moving in the same phase, *i.e.*, the distance between two consecutive crests or compressions or two consecutive troughs or rarefactions. It is represented by the Greek letter λ (Lambda). Its S.I unit is meter (m).

Velocity of Wave

The distance travelled by a wave in one second from a given point is called the velocity of wave. It is represented by V and is equal to $\left(V = \frac{\lambda}{T} = \nu\lambda\right)$. The S.I. unit is ms^{-1}.

The velocity of sound depends on:

1. Density
2. Elasticity of the medium
3. Temperature
4. Pressure

Speed

The speed of sound in air at 0°C is 330 m s^{-1}. The speed is more solids compared to liquids and more when compared to gas.

Sound Pressure

Pressure is the force per unit area. Thus, the sound waves creating pressure on the medium through which it propagates is measured Newton per sq. meter (Nm^{-2}). Sound pressure can also be defined the pressure deviation from the local ambient pressure caused by sound wave.

Intensity

The amount of sound energy that flows normally through unit area of the medium in unit time is called intensity. The time is generally measured in second. The unit of intensity is watt per $meter^2$ (Wm^{-2}). Energy per second per square meter = Joule per sec. per square meter $= Js^{-1} m^{-2} = Wm^{-2}$.

It should be remembered that the sound measuring units for intensities pressure and decibel (dB) are given in air, at room temperature and sea level pressure (1atm).

Classification of Sound

All sounds can be classified into two forms:

1. Musical sound
2. Noise

1. Musical Sound

The sound which produces pleasing effect on the ears of the listener is called musical sound. For example, sound produced by tuning fork, piano, violin, etc.

A musical sound consists of a series of harmonic waves following each other at regular intervals of time, without sudden changes in their amplitude.

2. Noise
A noise consists of a series of waves following each other at irregular intervals of time, with sudden changes in their amplitude. However, no sharp line can be drawn between a noise and sound.

7.1.1 Characteristics of a Musical Sound

A musical sound has three main characteristics namely loudness, pitch and quality.

Loudness
Loudness is defined as the listener's auditory impression of the strength of a sound. In other words, it is a subjective impression related to the intensity component of sound. The sound waves falling on the eardrum of the listener produce the sensation of hearing. The sensation of hearing which enables us to distinguish between a loud and a faint sound is called loudness. It depends upon the intensity of the sound as well as the sensitiveness of the ear of the listener. Also, the same sound may appear to be loud to one person and faint to other. Due to this reason, it is not entirely a physical quantity.

The unit of loudness is either decibel (dB) or bel (B). The intensity of sound, and hence its loudness, depends upon the amplitude of vibration of the source, the surface area of the vibrating source, the distance of the source from the listener, density of the medium through which sound travels from the source, presence of surrounding bodies, motion of the medium, etc.

Pitch
It is the characteristic of musical sound that helps the listeners in distinguishing a shrill note from a grave (dull or flat) one. A shriller sound is said to be of a higher pitch than the grave one. The higher pitch is found to be of greater frequency and lower pitch of lower frequency. However, the pitch is not stable but changes with frequency. The voice of a child is shriller than a boy and much shriller than a man.

Quality
It is the characteristic of musical sound that distinguishes between two or more sounds of the same pitch and loudness from each other.

Quality of a sound is determined by the number of harmonic components in it. More the number of components more pleasing is the

sound. The presence of different number of harmonics present in different musical instruments helps to identify them from each other.

7.2 NOISE

Noise is an unwanted, irregular, unpleasant and annoying sound. It is sound with no musical quality. The definition however, is subjective because one man's sound may be another man's noise. Noise can thus be defined as 'wrong sound, in the wrong place, at the wrong time'. However, it is always true that if the sound is loud and it prolongs for a longer period of time, it becomes noise for all. A given sound is pleasant when soft, but noisy when loud, pleasant when rhythmic, but noisy when repeated randomly. The word 'noise' comes from the Latin word *nausea* meaning 'seasickness' or from a derivative of Latin *noceo* = 'I do harm'.

Whereas sound is a pure tone, harmonically related, occurring at regular intervals and produces meaningful communications, noise is a complex mixture of a number of pure tones of varying frequencies and amplitudes.

Sound is a form of invisible energy, generated by a vibrating object and requires an elastic medium, which may be gas (air), liquid (water) or solid (metals, plastics, etc.) for its propagation, as it comprises wave motion. Sound waves are longitudinal waves, because the medium particles have periodic changes in displacement and pressure in the same direction of the waves.

A loudspeaker diaphragm which moves to and fro generates sound. As the diaphragm moves forward, it compresses the air near it. Now due to the forces developed by this compression, the air further away is progressively set in motion as the inertia of the air molecules is overcome. Now when the diaphragm reverses its direction of motion, it produces a rarefaction of air near it and a movement of the air molecules further away occurs progressively in the opposite direction. Thus, simultaneous compression and rarefaction set in, leading to pressure changes and we get sound.

The poor elasticity of air causes the disturbance (the pressure variation) which causes sound to travel at a slow speed of around 330 ms^{-1}. The extent of disturbance depends upon the rate of vibration of the vibrating object, the dissipative losses in the air molecules, the pressure of wind, temperature gradient and turbulence on the boundary surfaces.

Noise pollution can be defined as the unwanted sound dumped into the environment, unwanted due to the adverse effects it may have in relation to physical and mental health, displeasing effect, human communication, etc.

The unit of sound intensity is decibel (dB). Generally, the sound intensity from 0 to 100 dB is considered to be pleasant, but when the intensity exceeds 120 dB, it causes noise. Sound intensity of 130 dB is the upper limit of hearing and beyond this is the threshold of noise, causing pain to ear. The sound more than 130 dB causes noise pollution. However, the sound intensity received by the ear will be noise or not, depends on the distance, the listener is from the source and for how long he hears it. The distance is taken as one meter and time varies from person to person.

7.2.1 Mechanism of Hearing (Human Acoustics)

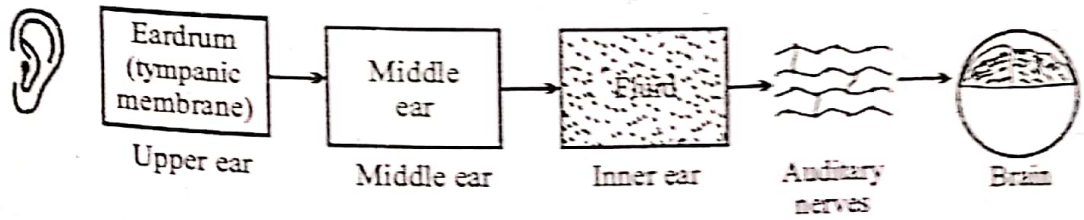


Fig. 7.4. Human acoustics

The science of human hearing sound is called human acoustics. Human acoustics specifically indicates the different processes that are involved in the perception of some sound by our ears.

Sound waves set up oscillations in the eardrum made up of tympanic membrane in the upper ear. The oscillations in the eardrum induce movements of the three small soft bones in the middle ear behind the eardrum.

The movements or oscillations in the middle ear pass through viscous fluid in the inner ear, creating oscillations of the fluid. These oscillations then reach the auditory nerves and are finally transmitted to the brain.

The oscillations or sounds are identified and interpreted in the brain, which has the capacity to analyze sound into different frequency components.

Human detectable frequency ranges are 2 to 20,000 Hz.

An eighteen year old person, with normal hearing, has audio r between 20 to 20,000 Hz. The audio sense is most sharp in the freq range 2000 to 5500 Hz.

Sensitivity of the ear varies from person to person. With ag hearing power decreases progressively. The ear is susceptible to d if it receives high intensity noise. However, the ear has some na protective device for short durations.

Intensity

Two important parameters of sound are sound pressure and inte They are measured in different units of different magnitudes. T common unit is decibel (dB). It is not an absolute value like kilog second, meter, etc., it is a ratio expressed in terms of logarithmic sc and is mathematically given as

$$\text{decibel (dB)} = 10 \log_{10} \frac{\text{I(measured intensity)}}{\text{I}_0\text{(reference intensity)}}$$

Thus, decibel measures how much intense is the sound compared reference intensity. Human beings can receive a vast range of intensi from around 1×10^{-12} W/m^2 to 1000 W/m^2.The reference intensity taken as 1×10^{-12} W/m^2 , which is considered to be an intensity le just audible to man. This, thus can be said to be threshold of hear Unfortunately, there are practical difficulties in accurately measur intensity. However, it is relatively easy to measure the consequence the energy passage and the pressure variation. Since the intensity directly proportional to the square of the pressure, that is

$$I_0 \propto P_0^2 \quad \text{and} \quad I \propto P^2$$

The sound pressure level (*SPL*) in *dB* is defined by

$$\text{SPL} = 20 \log_{10}\left(\frac{P}{P_0}\right)\text{dB}$$

where, P is the measured pressure in Nm^{-2} and P_0 the refere pressure, usually equals to 2×10^{-5} Nm^{-2} and is the nearest whol number corresponding to the reference intensity. Sound pressure leve (SPL) or sound level is thus, the logarithmic measure of the RMS valu of sound pressure of a sound relative to a reference value.

7.2.2 Measurement of Noise Levels

Noise level in decibel is measured with an instrument called sound level meter. It consists of three internationally accepted weighting networks, namely *A*, *B* and *C*. Noise level measured with network *A* is designated as dBA. In this scale, the frequencies to which human beings are more sensitive are given more weightage, in the assessment of effects on human hearing.

Noise surveys must be made in the entire area for evaluation of overall noise level and in the vicinity of individual noise sources under different environmental conditions. The noise emitted by individual sources must be carried at specified distance.

The disadvantage of dBA scale is that it is not related to human ear frequency response as well as environmental conditions, on which noise is measured. In case of dBA scale, although it is a characteristic of human ear capacity, it does not take account of peak noise levels, duration of noise and its quality. Therefore, other scales of measurement of noise levels with proper refinements of dBA scale are done. These are:

L_{10} (18 hours) Index

It is the arithmetic average hourly values of the noise level exceeded for 10 per cent of the time over 18 hours between 06:00 and 24:00 hours on any normal week day. This scale is used to measure road traffic noise in the UK. This scale of measurement considers peak noise level, fluctuation of noise due to nature of vehicle and traffic density.

Equivalent Perceived Noise Level (L_{epn})

It is the noise level measured in dBA scale and the value is taken to be (dBA scale +13). L_{epn} is used for measuring noise level of aircraft, recommended by International Civil Aviation Organization (ICAO). The measurement takes care of both the peak frequency of the aircraft and duration of flyovers.

Equivalent Noise Level (L_{eq})

It is the weighted average sound level over the time of measurement and is represented as L_{eq} and given in dBA unit. The time of measurement is specific and measured for a short duration usually when the noise

level is most prominent. If the measurement is done for different time durations the value will differ. If the measurement is done for a specific period of time started at the same time but in different place, it may not be same. Equivalent noise level is accepted by International Organization for Standardization (ISO). L_{eq} is used for measurement of noise level in the industrial, traffic as well as residential areas.

7.2.3 Noise Classification

Noise may originate from natural sources as well as through anthropogenic activities. The natural sources are cyclone, thunder, roaring of sea, volcanic eruption, etc. The anthropogenic sources are heavy machineries used in the industry, mechanized automobiles, trains, aero planes, washing machine, television, etc. The anthropogenic noise can be classified into

(*i*) Transport noise
(*ii*) Occupational noise
(*iii*) Neighbourhood noise

(*i*) Transport Noise

For simplification, transport noise is subdivided into three categories:
(*a*) Road traffic noise (*b*) Rail traffic noise (*c*) Aircraft noise

(*a*) *Road Traffic Noise*: The main causes of road traffic noise are the number of road vehicles and their high traffic speed. Heavy vehicles with faster speed create the maximum noise on the road. For example, heavy diesel engine trucks are the nosiest vehicles. All around the world, the traffic peak hour is from 10:00 a.m. in the morning to 6:00 p.m. evening. The traffic noise level is measured on the L_{10} (18 hours) index. The limit of noise level prescribed in India is 80 dBA, but is never followed.

(*b*) *Rail Traffic Noise*: It is not that serious like road traffic noise and aircraft noise. The noise is of lower frequency compared to road traffic noise. Introduction of diesel or electrical engines in place of steam engine, welded tracks and improve coaches has contributed a lot in reducing noise. Moreover, most railway tracks run through rural areas which are wider places surrounded by plants and trees. However, buildings located near railway tracks are exposed to noise menace. The rail traffic noise is measured on L_{eq} scale.

(c) *Aircraft Noise*: Aircraft noise is not created continuously but is intermittent. The noise is produced during takeoff, landing and flight. The faster and larger the aircraft, the more is the noise and thus, jet engines create the most noise. Although lesser in number, the aircrafts like fighter aircrafts which fly supersonically, become the nosiest source. The aircraft noise level is measured in L_{epn} scale (dBA scale +13).

(ii) Occupational Noise

This is mainly produced by industrial machines and processes like blasting operations, shipbuilding, factories and mills producing different kinds of products. Occupational noises are also due to machines used for domestic purposes such as television, washing machines, vacuum cleaners, etc. In industries, factories or mills, the workers are exposed for five days with 8 hours per day. In their houses, they are getting exposed for a longer duration, although frequency is lower compared to industry and factories. Million and million of people working in the industries are the main victims. The high degree of noise causes lowering of hearing capacity to a great extent.

Table 7.1. *Some Industrial Noise Levels*

Industrial source	*Noise Level (dBA)*
Steel plate riveting	130
Boiler marker's shop	120
Farms tractor	103
News paper press	101
Milling machines	82

(iii) Neighbourhood Noise

There are a variety of sources of noise that disturb and annoy people by interfering with their comfort. The sources are loud TV, stereo, radio sets, barking of dogs, garaging the automobiles, starting of the two wheelers used by people, without considering the harmful effects which they might have on the nearby neighbours. The use of machines for building construction and building demolition are also sources of serious nuisance. Use of loud speakers at public functions, in disco music and dance in late evenings also causes noise nuisance to the nearby residents.

The prescribed permissible sound level for cities by **Central Pollution Board of India** is given below:

Area	Day (dBA)	Night (dB
Industrial	75	65
Commercial	65	55
Residential	50	45
Educational Institution, courts, hospitals (most sensitive area)	50	40

7.2.4 Effects of Noise Pollution

Physiological Effects

(*a*) Acute effects: Such effects by noise depend upon the pressure and frequency. As is known, a sound of 65 (dBA) is the noise level for conversation heard at a distance of one meter. Sound of 110 (dBA) gives discomfort and 135 (dBA) is painful and 150 (dBA) might kill a person. A sound level in the range of 110–150 (dBA), affects respiratory system, causes loss of physical control and other physiological changes might occur.

Loud sounds can cause an increased secretion of various hormones of the pituitary gland, leading to increased blood sugar level, reducing immune system capability, effecting liver, heart, brain and kidney

(*b*) Chronic effects: The major effect is hearing loss. A person exposed to high noise levels goes deaf more quickly compared to the person exposed to relatively noise free environment. Such effects depend on pressure, frequency and period of exposure. The hearing loss starts in the frequency range of about 4000 Hz.

Mental Health

Noise affects mental capability, thereby reducing mind concentration and at higher frequencies leads to mental disorientation.

Work Efficiency

Noise causes chronic headache and irritability, thereby reducing work efficiency.

Industrial Accidents

Noise interfering with sound system might mask the warning signals thereby increasing the incidence of errors making accidents more likely.

Communication

The sound signal is distorted if the frequency of noise coincides with it. Thus, we have to raise the volume of our TV set or radio set to overcome the interferences of noise frequency, thereby creating further noise.

Personal Comfort

To maintain a healthy body and a healthy mind, one needs a minimum specific period of proper sleep. Noise may contribute to distress and emotional disturbance. This effect is more severe on old people and children. For old people it might cause neurotic problems and for children, affect their behavioral pattern.

Effects on Birds

Migratory birds are now found to be the victims of noise pollution. The high noise pollution, along with high-rise buildings around a place can reduce the number of migratory birds. Such an effect is already observed in Alipore Zoo in Calcutta. Whereas, the number of migratory birds was 15,000 in 1982 it became 2,000 in 1990.

Table 7.2. *Psychological and Physical Effects of Noise*

Noise Level (dBA)	*Effects*
135	Painful
110	Discomforting
80	Annoying
65	Heard at a distance of 1 meter
150	Significant change in pulse rate
160	Minor damage of hearing
190	Major damage in a short time

7.2.5 Noise Threshold Limit Values

The noise threshold limit values as per the American National Standard Specification of sound level meters, SI (197) TYPE 52*A*, is given in the table 7.3.

Table 7.3. *Noise Threshold Limit Values*

Duration Per Day (Hour)	*Sound Level (dBA)*
16	80
8	85
4	90
2	95
1	100
½	105
¼	110
1/8	115

When daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect needs to be considered rather than the individual effect of each. When the sum of following fractions

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots\ldots \frac{C_n}{T_n}$$

exceeds unity, then the mixed exposure is considered to exceed the threshold limit values. C_n indicates the total duration of exposure at a specific noise level and T_n indicates the total duration of exposure permitted at that level.

***Example 1*:** In a work area, the noise levels are read as 100 (dBA) for 3 hours a day, 85(dBA) for 2 hours a day and 80 (dBA) for remaining 3 hours a day.

***Solution*:** The problem is to find out the permissible durations for each noise level. The permissible exposures are 100 (dBA) = 1 hr, 85 (dBA) = 8hrs, 80 (dBA) = 16 hrs.

Now when we add the ratios,

Noise levels (dBA)	100	85	80
Measured (hrs)	3	2	3
Permissible (hrs)	1	8	16

Hence,

$$\frac{3}{1} + \frac{2}{8} + \frac{3}{16} = 3 + \frac{1}{4} + \frac{3}{16} = \frac{55}{16} = 3\frac{7}{16}$$

This exceeds the permissible limit of 1.

***Example 2*:** Noise in an area measures 90 (dBA) for 2 hours, 80 (dBA) for 3 hours and 75 (dBA) for 1 hour.

***Solution*:**

Noise levels (dBA)	90	80	75
Measured (hrs)	2	3	1
Permissible (hrs)	4	16	any period of time (∞)

Hence, $\frac{2}{4} + \frac{3}{16} + \frac{1}{\infty} = \frac{2}{4} + \frac{3}{16} + 0 = \frac{11}{16}$

The exposure is thus, within limits.

7.2.6 Impulsive or Impact Noise

There are some recommended threshold limit values of impact or impulsive noise levels. For time intervals, greater than one second is considered as impulsive or impact noise and less than one second as continuous. Exposure to more than 140 dBA peak sound pressure level is never permitted.

Table 7.4. *Threshold Limit Values having Impulsive or Impact Noise*

Sound Level (dBA)	*Permitted Number of Impulses or Impact Per Day*
140	100
130	1,000
120	10,000

7.2.7 Monitoring

It is very essential to monitor environmental conditions continuously to minimize the risk of noise exposure. The long-term program undertaken to see that the measured noise level does not vary and protective action taken remains effective, more preventive measure can be introduced when necessary. For better confirmation, medical examinations of workers can ascertain whether the preventive action taken has proved satisfactory or not.

7.2.8 Noise Control

The noise generated in the environment can never be eliminated completely, however, it can be controlled. Many new technologies are introduced to curb noise. There are, however, some easy ways to curb noise besides introduction of new technology. The basic difference of noise pollution from other types of pollution is that it does not leave any residue in the environment, but it creates enormous physical and mental health problem in persons continuously exposed to it for a considerable time. As we cannot see the sound wave and as it does not leave any residue, it is not given that importance and people are continuously exposed to it. Thus, it is the demand of the hour to implement new stringent laws, such as motor vehicle act, introduce new regulation to lower speed limits of vehicles, promote education and research creating

awareness among the public about the harmful effects of noise pollu through radio, television and newspapers.

The noise created from the heavy machinery used in the industry well as other community can be curbed by taking measures at the sour at the noise transmission path and at the receivers. Source is the m route of noise generation. If noise is completely abated at the sou the other two need less nourishment. However, due to various machine parts involved in the source, noise cannot be abated completely. So we take care of the three areas all together, noise can be eliminated a maximum level.

(*a*) Control at Source

In the industrial establishment, it can be done by proper design, prop operation and regular maintenance of the machines. The industry shou be located at open spaces far off from the residential areas.

As far as community noise is concerned, the loud speakers, radi and music system should not be allowed to cross the threshold intensity

(*b*) Control at Path

The noise transmission path can be covered with such material, which can absorb the sound, can insulate the sound. Sound absorbers can b glass wool, porous panels, perforated panels, tiles, carpets, curtains etc. These materials are generally porous which reduce reflection of sound.

Sound insulators reduce sound transmission through barriers. Sound insulating materials could be glass, steel, ceramic materials, concrete etc.

Vibration control of the machinery is generally done by mounting the machine on a base plate or an inertia block like concrete block.

The various other measures of path control resources are:

(*i*) ***Acoustic enclosures***: This can be done by putting close fitting enclosure around the machine, keeping high noise generating machine in a separate room at a relatively long distance. The walls of the enclosures are also made with acoustically lined materials, such as glass fiber or fiber wool inside the wall.

(*ii*) ***Noise barriers***: This can be done by constructing walls with hard and dense materials to reflect sound or porous material to absorb sound and by placing them closest to the noise source. To achieve high degree

of efficiency, the gaps or the joints of barriers are eliminated, so that the sound does not leak through and reduce efficiency. However, sound will lead the machine operator to get exposed to the noise. Some common examples of noise barriers are glass fibers, brickwork, fiberboard, etc.

(iii) ***Silencers***: Silencer is a hollow material, shaped in such dimensions that it reduces sound transmission, but allows the gases (incoming as well as outgoing) to pass through it. The silencer may absorb the sound or reflect the sound or if designed properly can function in both ways in a single system, thereby reducing noise intensity.

The materials generally used are stainless steel, tin plate, stainless iron which acts as a reflector of sound and when coated with fiberglass the sound intensity reduces to a large extent due to the absorption of sound. Silencers are generally used in automobiles and transport vehicles.

(iv) ***Reduction of noise produced due to vibration of machine***: Installation of a machine on the floor contributes to high noise pollution to a large area around it. The best way to solve such problem is to place the machine on a thick steel plate, isolated from the other by a thick block of rubber.

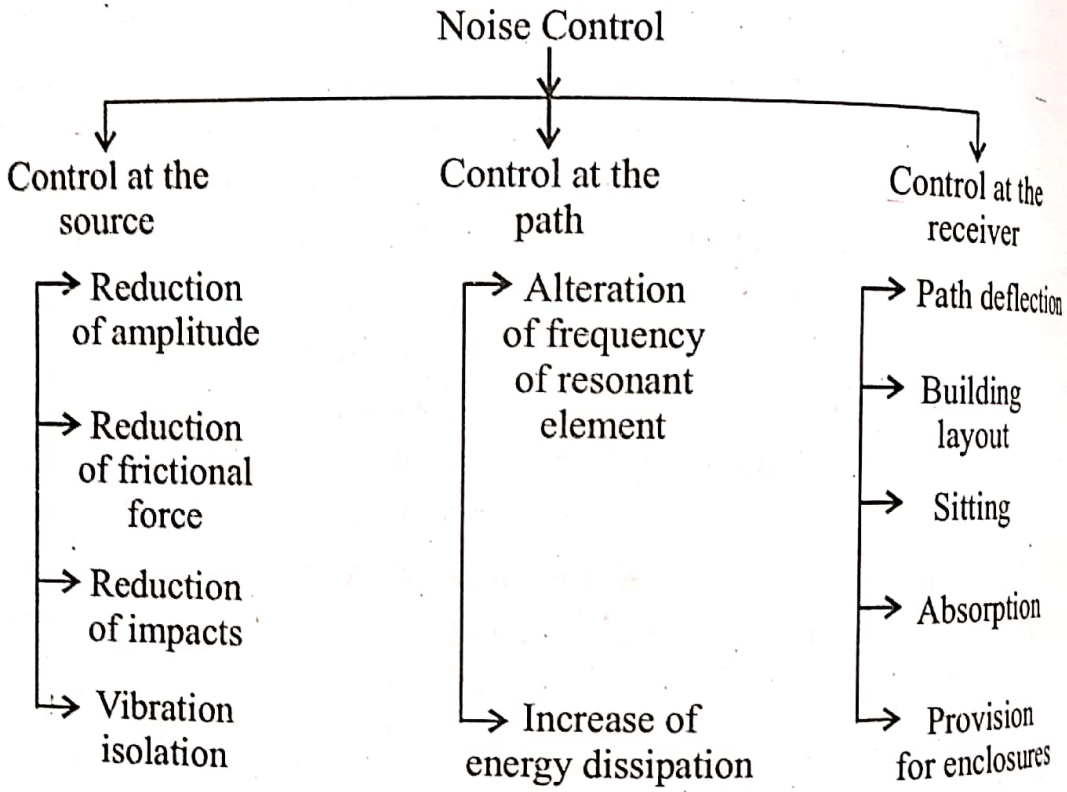
(c) Control at Receiver (Personal protection)

No matter how much precaution be taken, how much technology is introduced, it is not possible to nullify noise. Thus, personal protection is very essential for the safety of the workers. For such cases, ear protection and in extreme cases personal isolation will help a lot. The commonly used hearing protectors are earplugs, ear muffs, etc.

In an extreme case, the person can be isolated from the source to stay in an air conditioner enclosure or a thick walled sound absorbing room, with a viewing window and occasionally, can go to the operating room thus, minimizing noise exposure. In an industrial establishment, administrative control helps a great deal. The workers should be given shift duties, so that an individual or groups are not exposed to the noise for a longer period of time.

Lastly, it should be mentioned that plants and trees have a greater capacity for reduction of noise. Plants are efficient absorbers of noise, especially noise of high frequency. Thus, plantations along highways, streets and industrial areas should be done. This is one of the reasons due to which rail traffic noise or other road transport noise is less when they run through highways having green plantation on both sides. Air

traffic noise can be curtailed by growing green vegetation belt of short to medium height around the airport.



7.2.9 Noise Measuring Equipments

The commonly used noise measuring equipments are:

(*i*) Sound Level Meter

It consists of a non–directional microphone coupled to an amplifier to transform sound wave (sound pressure level) to a proportional electric signal. It measures the RMS value of noise and can also be calibrated to measure the peak level of sound. The sound level meter (IEC 123) is cheap to do rough estimation of high and low frequency sound level, whereas (IEC 179) are expensive but have high degree of accuracy.

(*ii*) Cassette Recorder

It is cheaper and used to store noise for rough evaluation. It is used for digital recording of sound pressure level (SPL) for computer evaluation.

(*iii*) Magnetic Tape Recorder

It is a costly instrument compared to cassette recorder. Such recorder is directly fed through sound level meter or microphone. It records the noise more accurately and stores it for better evaluation.

(iv) Pen Recorder

Pen recorder can be fed directly or from sound level meter or magnetic tape recordings. Pen recorder can do continuous recording of sound pressure level (SPL), as well as discontinuous recording of instantaneous sound pressure level (SPL) from the received noise.

(v) Noise Average Meter (L_{eq} Meters)

Noise average meter measures L_{eq} sound levels with great accuracy. Noise average meter is fed directly or from magnetic tape recordings.

(vi) Noise Analyzer

This instrument is fed directly or from magnetic tape recordings. It consists essentially of a sound level meter (IEC179), which feeds a noise average meter. It can provide digital display also.

Some other commonly used instruments are impulse noise meters, vibration meters, noise limit indicators, etc.

7.2.10 Application of Sound Waves

The ultrasonic waves (frequency above 20,000 Hz), are used:

1. To detect the presence of hidden objects in water such as sunken ship, hidden iceberg, sea rock, submerged submarine.
2. To measure the ocean depth.
3. To detect the flows in metal block without damaging it.
4. To find out the level of a liquid in a metallic tank.
5. For medical diagnosis and therapy in place of harmful electromagnetic x-rays. A very common example is ultrasonography (USG).

7.2.11 Prevention of Noise Pollution

Noise pollution has harmful effects on both our body and mind. The safe intensity level of sound, as prescribed by World Health Organization (WHO) is 45 dB. But in the present era, it is rarely maintained and the result is 'Noise Pollution'. In order to lead a healthy life, abatement of noise pollution should also be considered seriously. The various sources of noise pollution are road traffic noise, rail traffic noise, aircraft noise, industrial noise and neighborhood noise, etc. There are a variety of effective strategies for abating noise levels, such as use of noise barriers, limiting vehicle speeds, improving tire design, limiting heavy duty vehicles

and use of silencers in the vehicles for road traffic noise, designing quieter jet engines, altering flight paths for aircraft noise, improving technology for electric locomotives for rail traffic noise, redesigning of industrial equipment, using acoustic screens and barriers for industrial noise. One of the best ways of reducing noise pollution is through making green belt around the residential areas, around airport and on the sides of the road where the vehicles and trains run.

Besides all the above measures, following steps should be followed to prevent noise pollution to the highest extent.

- raising public awareness about the effect of noise pollution.
- distributing up-to-date information regarding noise pollution.
- strengthening laws and governmental efforts to control noise pollution.
- establishing networks among environmental professionals, governmental and all other activist groups working on noise pollution issues.
- helping and protecting activists working against noise pollution.

Lastly, it can be mentioned that two very simple measures can help a lot in abating noise pollution.

The cities can be developed in a planned manner. Industry and transport areas can be separated into zones, residential areas may be made at least 20 meters away from the main streets and the space be thickly planted.

Heavy vehicles should not be allowed to use narrow streets and the use of horns and pressure horns be prohibited.

QUESTIONS WITH ANSWERS

Q. 1. (*a*) What is noise and noise pollution?
(*b*) Discuss in details the different types of noise.
(*c*) What is the unit of measurement of sound?
(*d*) In which frequency range audio sense is most sharp?
(*e*) What is the human detectable frequency range?

Ans. (*a*) Noise is an unwanted, irregular, unpleasant and annoying sound, *i.e.*, sound with no musical quality. The definition however, is subjective,

because one man's sound may be another man's noise. Thus, noise can be defined as 'wrong sound, in the wrong place, at the wrong time'. However, it is always true that if the sound is loud and it prolongs for a longer period of time, it becomes noise for all. A given sound is pleasant when it is soft but noisy when loud, pleasant when rhythmic but noise when repeated randomly.

Noise pollution can be defined as the unwanted sound dumped into the environment, without considering the adverse effects it may have (physical and mental health, displeasing effect, human communication, etc.).

(*b*) The different types of anthropogenic noise are (1) transport noise (2) occupational noise (3) neighbourhood noise.

1. **Transport noise:** For simplification the transport noise is sub–divided into three categories:

(*i*) Road traffic noise (*ii*) Rail traffic noise (*iii*) Aircraft noise

(*i*) **Road traffic noise:** The main causes of road traffic noise are the number of road vehicles and their high traffic speed. Heavy vehicles with faster speed create the maximum noise on the road. For example, heavy diesel engine trucks are the noisiest vehicles. All around the world, the traffic peak hour is from 10:00 a.m. in the morning to 6:00 p.m. evening. The traffic noise level is measured on the L_{10} (18 hours) index. The limit of noise level prescribed in India is 80 dBA but is never followed.

(*ii*) **Rail traffic noise:** It is not that serious like road traffic noise and aircraft noise. The noise is of lower frequency comparative to road traffic noise. Introduction of diesel or electrical engines in place of steam engine, welded tracks and improved coaches has contributed a lot in reducing noise. Moreover, most railway tracks run through rural areas or wider places surrounded by plants and trees. However, buildings located near the railway tracks are exposed to noise menace. The rail traffic noise is measured on the L_{eq} scale.

(*iii*) **Aircraft noise:** Aircraft noise is not created continuously but intermittent. The noise is produced during the take off, landing and flight. The faster and bigger the aircraft, the more is the noise and thus, jet engines create the most noise. Although lesser in number, the aircraft

like fighter aircrafts which fly supersonically become the noisiest source. The aircraft noise level is measured in L_{epn} scale (dBA scale +13).

2. Occupational noise: This is mainly produced by industrial machines and processes like blasting operations, shipbuilding, factories and mills producing different kind of products. Occupational noises are also due to machines used for domestic purposes such as, television, washing machines, vacuum cleaners, etc. In the industries, factories or mills the workers are exposed for five days, with 8 hours per day. In their house they get exposed for a longer duration, although frequency is lower compared to industries and factories. Million and million of people working in the industry are the main victims. The high degree of noise causes lowering of hearing capacity to a great extent.

3. Neighbourhood noise: There are varieties of sources of noise that disturb and annoy people by interfering with their comfort. The sources are loud TV, stereo, radio sets, barking of dogs, parking the automobiles, starting the two wheelers, used by neighbours without considering the harmful effect it might have on the nearer neighbors. The use of machines for building construction and building demolition also are sources of serious nuisance. Use of loud speakers in public functions, disco music and dance in late evenings, also causes noise nuisance to the nearby residents.

(*c*) The common unit used for measurement of sound is 'decibel'.

(*d*) The audio sense is most sharp in the frequency range of 2000 to 5500 Hz.

(*e*) Human detectable frequency range is 2 to 20,000 Hz.

Q. 2. (*a*) What are the effects of noise pollution?

(*b*) What is 'Noise dose'?

(*c*) What is 'Noise Threshold Limit Value'?

Ans. (*a*) The generation of noise in the environment is regarded as pollution because it affects life. Noise at a certain limit although can be tolerable, but excessive noise affects life adversely. Noise affects in three levels.

(*i*) Audiographic level – in relation to hearing mechanism.

(*ii*) Biological level – in relation to biological functioning.

(iii) Behavioural level – in relation to sociological behaviour.

(i) **Audiographic effect:** Repeated exposure to noise level within 110 dB(A) to 135 dB(A) might result in temporary hear loss, for long exposure however, it might lead to permanent hearing loss.

In extreme cases if a person is exposed to repeated sounds of high intensity (> 135dB (A)), the sensory cells of the ear as well as the delicate tympanic membrane might get damaged permanently. The hearing loss starts at the frequency range of about 4000 Hz.

(ii) **Biological effect:** The following are the main biological effects of noise pollution.

(*a*) Headache, continuous exposure may lead to chronic headache.
(*b*) Increase in heart beat rate.
(*c*) Nervous breakdown.
(*d*) Increased blood sugar level.
(*e*) Loss of memory.

(iii) **Psychological effect:** The following are the main psychological effects of noise pollution:

(*a*) Reduction in mind concentration.
(*b*) Reduction in work efficiency.
(*c*) Depression and fatigue.
(*d*) Mental disorientation.

(*b*) 'Noise dose' estimates the limits of intensity of noise level which can be tolerated and which cannot, under a given specific time. This estimation is important as it can suggest the time a person can get exposed to a certain sound level (dBA). If it is not followed, the long exposure might lead to hearing loss. For higher level of sound, one should not get exposed to a longer time but for lower level of sound the time can be extended.

Level (dBA)	*Dose Time*
90	88 hours
95	4 hours
100	48 minutes
110	4.8 minutes
120	28.8 seconds
130	2.88 seconds

(*c*) When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect needs to be considered, rather than the individual effect of each. When the sum of following fractions:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots\ldots \frac{C_n}{T_n}$$

exceeds unity, then the mixed exposure is considered to exceed the threshold limit values. C_n indicates the total duration of exposure at a specific noise level and T_n indicates the total duration of exposure permitted at that level.

Q.3. (*a*) What is sound?

(*b*) What is the difference between sound and noise?

(*c*) Define noise pollution in a broad perspective?

(*d*) What are the drawbacks of dBA scale?

Ans. (*a*) Sound may be defined as a form of energy giving the sensation of hearing and is produced by vibrations as longitudinal mechanical waves, in materials including solids, liquids and gases and is transmitted by oscillations of atoms and molecules of matter. Sound cannot travel in vacuum and moves with a definite velocity and undergoes reflection, refraction, interference and diffraction.

(*b*)

Sound	*Noise*
1. It is pleasant to hear.	1. It is unpleasant to hear.
2. It has a constant pitch.	2. It has a constantly varying pitch.
3. It has a regular periodic motion.	3. It has a no regular periodic motion.
4. It produces meaningful communication.	4. It produces no meaningful communication.
5. Its unit is Hertz (Hz) Hz = cycles/sec.	5. Its unit is decibel (dB) $dB = 10 \log_{10} \frac{\text{Intensity measured}}{\text{Reference intensity}}$

(*c*) The disturbing pollution created by noise due to some unwanted continuously varying pitch, causing harm or damage to human ear is called noise pollution.

Noise pollution can also cause pathological or psychological disorder. High frequency or ultrasonic sound above the normal

audible range can affect semicircular canals of the inner ear and make one suffer from nausea and dizziness.

Noise has become a part of our environment. With growth in industry the level of noise has been increasing continuously. In the nineteenth century the development of the steam engine, petrol engines and technological machinery, in industry resulted in an increasingly noisy environment. In the twentieth century this has been further accelerated by the introduction of diesel engines, turbo prop and jet engines, high-tech machines, construction site machinery and increased road traffic.

Noise is considered to be one of the dimensions of pollution which leads to environmental degradation and also poses health and communication hazards.

Unlike other forms of pollution, such as air, water and hazardous materials, noise does not remain long in the environment. However, while its effects are immediate in terms of annoyance, they are cumulative in terms of temporary or permanent hearing loss.

(*d*) Drawbacks of the dBA scale are as follows:

1. It is not refined enough to take care of peak noise levels.
2. It does not take into account the duration of noise exposure.
3. It fails to consider the quality of noise which is the aspect of specific environmental noise situations.

Q. 4. (*a*) Calculate the intensity of 100 dB sounds.
(Reference intensity = 1×10^{-12} w/m^2)

Ans.

We know, sound level $(dB) = 10 \log_{10} \frac{I}{I_0}$

where, I = measured intensity, and

I_0 = reference intensity = 1×10^{-12} w/m^2

Thus, according to the problem,

$$100 = 10 \log_{10} \frac{I}{1 \times 10^{-12}} \quad \text{or} \quad 10 = \log_{10} \frac{I}{1 \times 10^{-12}}$$

or $$I = 10^{10} \times 10^{-12} = 10^{-2}$$

The intensity is 1×10^{-2} w/m^2.

(*b*) If two machines produce 50 dB sounds simultaneously, what will be the total sound level?

Ans. For 1st machine,

$$L_1 = 10 \log_{10} \frac{I_1}{I_0}$$

or $$50 = 10 \log_{10} \frac{I_1}{I_0} \quad \text{or} \quad I_1 = 10^5 \times I_0 \qquad \ldots(1)$$

Similarly, for the second machine also,

$$I_2 = 10^5 \times I_0 \qquad \ldots(2)$$

The total intensity (I_3) of sound becomes,

$$I_3 = I_1 + I_2 = I_0 (10^5 + 10^5) = I_0 (2 \times 10^5)$$

Hence, sound level $L_3 = 10 \log_{10} \frac{I_0 (2 \times 10^5)}{I_0} = 10 \log_{10} (2 \times 10^5)$

$$= 53.01300 \; dB$$

(*c*) Add a sound level of 80 *dB* to 120 *dB*.

Ans. In the first case, when the sound level is 80 *dB*, we have

$$80 = 10 \log_{10} \frac{I_1}{I_0} \quad \text{or} \quad I_1 = I_0 \times 10^8 \qquad \ldots(1)$$

Similarly, in the second case, when the sound level is 120 *dB*, we have

$$120 = 10 \log_{10} \frac{I_2}{I_0} \quad \text{or} \quad I_2 = I_0 \times 10^{12} \qquad \ldots(2)$$

The total sound intensity becomes,

$$I_{total} = I_1 + I_2 = I_0 (1 \times 10^8 + 1 \times 10^{12})$$

So, the resultant sound level L_1 becomes

$$L_1 = 10 \log_{10} \frac{I_{total}}{I_0} = 10 \log_{10} \frac{I_0 (1 \times 10^8 + 1 \times 10^{12})}{I_0}$$

$$= 10 \log_{10} (10^8 + 10^{12}) = 120.00434 dB$$

(d) Noise in an area is measured as 95 dBA for 1 hour, 90 dBA for 3 hours, 100 dBA for 30 minutes and 75 dBA for 3 hours. The permissible noise exposure duration of 100 dBA is 1 hour, 95 dBA is 2 hours, 90 dBA is 4 hours and 75 dBA is any time. Find out whether the permissible limit has exceeded or not and also state if the condition is good for the health of a worker or not.

Solution.

Noise level dBA:	100	95	90	75
Measured hours:	½	1	3	3
Permissible hours:	1	2	4	∞

We know noise threshold limit value $= \frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots\ldots$

where, C = actual hours exposed to a particular noise level.

T = permissible hours of exposure to that noise level.

The noise threshold limit value $= \frac{\frac{1}{2}}{1} + \frac{1}{2} + \frac{3}{4} + \frac{3}{\infty} = 1\frac{3}{4}$

As the noise threshold limit value crosses the permissible limit, *i.e.*, 1, therefore, the existing working environment is not good for the worker.

EXERCISE

Q. 1. What is sound? What are the characteristics of a musical sound? What do you mean by pitch and quality of sound?

Q. 2. What is noise? In what way does noise differs from sound? What is the mechanism of hearing? What do you mean by sound pressure level and intensity of sound? What are the units of intensity?

Q. 3. What are the human detectable frequency range and normal hearing frequency range? How does the sensitivity of ear vary from person to person?

Q. 4. Define L_{10} (18 hrs.) Index, Equivalent perceived noise level and Equivalent noise level.

Q. 5. In how many classes noise can be classified? Discuss in detail the classification of noise.

Q. 6. What do you mean by noise pollution? What are the effects of noise pollution on living organisms? How can you control noise pollution?

Q. 7. Write short notes on Noise Threshold Limit Values and Impulsive or Impact noise.

Q. 8. What are the different equipments used in measurement of noise? What are the applications of sound wave?

Q. 9. Problem sums:

(*a*) Calculate the intensity of 101 *dB* sound.
(Reference intensity = 1×10^{-12} W/m^2)
(**Ans.** $1 \times 10^{-1.9}$ W/m^2)

(*b*) Two machines can produce 50 *dB* sound and 75 *dB* sound. If these machines start from the same place and at the same time, what will be the resultant sound level? (**Ans.** 75.014 dB)

(*c*) The measured noise in an area is 70 *dB* for 2 hours, 90 *dB* for 45 minutes, 100 *dB* for 30 minutes and 110 *dB* for 10 minutes. Find out the noise threshold limit values and predict whether the working environment is healthier from the point of noise pollution.
(**Ans.** 1.354; not healthy)