Chapter 08

Noise Pollution

INTRODUCTION

Sound in the environment is caused by vibrations in the air that reach human ears and stimulate a sensation of hearing. When the sound becomes loud or disagreeable or unwanted it becomes noise. Noise, therefore can be defined as unwanted sound, pollutant, which produces undesirable physiological and psychological effects in an individual, by interfering with one's social activities like work, rest, recreation, sleep etc.

The noise, as pollutant, infact, differs from other pollutants in the sense that it is transient in nature and is not a continuing or persisting phenomena. When once the noise pollutions stops, the environment becomes free of this pollutant unlike other pollutants like gases and particulate matter, which continue to linger on after once entering into the air atmosphere.

8.1 The Effects of Noise

The various effects of noise can be divided into the following categories.

8.1.1 Noise induced Annoyance

One of the most important effect of noise on human is announced and irritation due to disturbance. A noise can be said to be annoying when a person does not like the same and hence wants the sound to be put off or wish to leave the noisy area at the earliest.

8.1.2 Noise induced Disease

Noise may produce several undesirable physiological and psychological diseases in human beings. The diseases caused may include anxiety, tenseness, nervousness headaches fatigue, nausea, insomnia, high blood pressure, high pulse rate, greater perspiration, gastric secretions etc.

8.1.3 Sleeplessness

The noise may induce sleep disturbances including shorter sleep duration, more frequent awakenings, etc. sleep disturbance due to noise may depend upon the characteristic of the noise, such as its frequency, loudness and continuity/intermittency.

8.1.4 Communication Interference

Noise can badly disturb communication when a person is speaking on telephone or talking face to face. This may require greater speaking effort on the part of the speaker and much more care on the part of the listener.

8.1.5 Noise Induced Hearing Loss

Exposure of human ears to intense noise for long enough duration may cause damage to inner ear, thereby increasing ones ability to hear.

8.1.6 Effect of Noise on Wildlife

Wildlife, like humans, is also badly affected by noise. Health of several zoo-animals are adversely affected by noise. They become inactive and dull under noisy conditions.

8.2 Characteristics of Sound and its Measurement

- Sound is produced in the environment by alternating pressure changes in the air and is caused by the vibrations of solid objects or separation of fluids as they pass over, around or through holes in solid objects. These vibration cause the surrounding air to undergo compression, then rarefaction, again compression, then rarefaction and so on.

NOTE: Alternating compression and rarefaction of the surrounding air produces sound waves which propagate in the form of sinusoidal path.

- The times between the successive peaks or troughs of oscillation is called the period (P), and its inverse which represents the number of times a peak arrives in a second, is called the frequency (f). Hence

$$P = \frac{1}{f}$$

- The distance between successive peaks or troughs is called the wave length (λ), which is related to frequency (f) by the relation.

$$\lambda = C\frac{1}{f} \quad \text{where, } C = \text{the velocity of sound waves}$$

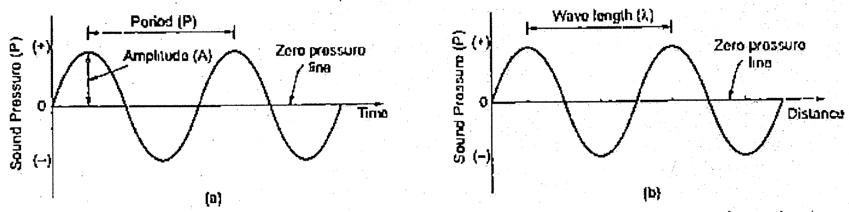


Fig. 8.1 Typical sinusoidal sound waves produced by alternating compression and rarefaction of air molecules.

- The amplitude (A) of the wave is the height of the peak sound pressure measured above or below the zero pressure line. The equivalent pressure of such a sine wave is represented by root mean square pressure (P_{rms}) as.

$$P_{rms} = \sqrt{\overline{p^2(t)}} = \sqrt{\frac{1}{T}\int_0^T p^2(t)\cdot dt}$$

where, $p(t)$ = pressure at time t

NOTE: Sound pressure = Total atmospheric pressure – barometric pressure

- The power of sound (w) is defined as the rate of doing work by a travelling sound wave in the direction of the propagation of the wave. The energy transmitted by a sound wave in the direction of its propagation is thus, defined as its power and is represented in watt in *S.I.* units
- The sound intensity (I) is used to measure sound. It is defined as the sound power averaged over the time, per unit area normal to the direction of propagation of sound wave. Intensity and power of a sound wave are related by the equation

$$I = \frac{W}{a}$$

where, I = Intensity of sound wave in watt/m²
W = Power of sound wave in watts (averaged over the time)
a = A unit area ⊥ to the direction of wave motion

- Sound intensity (I) is further related to r.m.s sound pressure by the equation

$$I = \frac{P_{rms}^2}{\rho . C}$$

where, P_{rms} = r.m.s sound pressure in pascal (P_a)
ρ = density of air or medium in which sound wave travelling in kg/m³
C = velocity of sound wave in m/s.

8.2.1 Levels of Noise

- The sound presence of the faintest sound that can be heard by a normal healthy individual is about 20 micropascal (μ - P_a). The sound level (L) is represented as

$$\boxed{L = \log_{10} \frac{Q}{Q_0} \text{(bels)}} \quad ...(i)$$

where, Q = Measured quantity of sound pressure or sound intensity
Q_0 = Reference standard quantity of sound pressure or sound intensity, as the case may be
L = Sound level in bel (B)

- Bel is large unit, a smaller unit is decibel

$$\boxed{L = 10 \log_{10} \frac{Q}{Q_0} dB} \quad ...(ii)$$

The reference standard quantity Q_0 in the above equation is taken to be equal to 20 μPa, when sound pressure is measured.

- Sound Pressure Level

$$\text{Sound pressure level} = L_P = 10 \times \log_{10}\left(\frac{P_{rms}}{20\ \mu\text{Pa}}\right)^2$$

$$\boxed{L_P = 20 \log_{10}\left(\frac{P_{rms}}{20\ \mu\text{Pa}}\right)} \quad ...(i)$$

The sound pressure levels so measured are reported as dB_{re} : 20 μPa.

Example 8.1 The sound pressure level for a jet plane on the ground with sound pressure of 2000μ bar should be
(a) 60 decibel (b) 100 decibel
(c) 140 decibel (d) 180 decibel

Ans. (c)

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

P is sound pressure in N/m²
P_0 is reference pressure (2 × 10⁻⁵ N/m²)
For given sound pressure

$$P = 2000\ \mu \text{ bar} = 200 \text{ N/m}^2$$

$$\therefore \quad \text{SPL} = 20 \log\left(\frac{200}{2 \times 10^{-5}}\right) = 140 \text{ dB}$$

8.2.2 Sound Intensity Level

The reference standard quantity Q_0 in equation (ii) is taken to be equal to 10^{-12} W/m², when sound intensity level is measured. The sound intensity level is thus given as

$$\boxed{L_I \text{ in dB} = 10 \log_{10}\left(\frac{I}{10^{-12}}\right)} \text{ where, } I \text{ is in W/m}^2 \quad ...(iv)$$

NOTE
(i) Out of these two terms, i.e. sound pressure and sound intensity sound pressure level on reference scale of 20 mPa is usually adopted to express, sound levels of course in decibels.
(ii) Sound intensity varies as square of the sound pressure (rms).
(iii) An increase of 20 dB in sound pressure level will correspond to the sound pressure (P_{rms}) or loudness of sound, increased by 10 times.
(iv) One dB is the faintest sound which can be perceived by human ear and the maximum sound which tolerated by human ear is about 180 dB.

- The addition of such sound levels cannot be done by simple arithmetic addition because of the log scale involved. Hence if we consider 50 decibel noise and want to add another 50 decibel noise, it will not make upto 100 decibel noise, but will make up only 53 decibel noise, as calculated below.

$$50 \text{ decibel} = 20 \log_{10}\left(\frac{P_{rms}}{20}\right)$$

$$\therefore \quad \left(\frac{P_{rms}}{20}\right) = \text{antilog}\left(\frac{50}{20}\right) = 316.227$$

$$\therefore \text{ 50 decibel + 50 decibel in r.m.s} = \sqrt{(6324)^2 + (6324.55)^2} = 8944.26\ \mu\text{Pa}$$

$$\text{Sound pressure level} = 20 \log_{10}\left(\frac{8944.26}{20}\right) \text{dB} = 53 \text{ decibel}$$

- 'Sound pressure level' mentioned gives a physical measure of sound, yet it can not give perfect indication of loudness, because it does not account for the frequency of sound. The frequency of noise, thus, becomes an important factor in measuring a sound.

Example 8.2 Which one of the following is the correct sound intensity expression with usual notations?
(a) dB = $10 \log_{10}(I/I_C)^2$ (b) dB = $10 \log_{10}(I/I_0)$
(c) dB = $10 \log_{10}(I - I_0)^2$ (d) dB = $10 \log_{10}(I - I_0)$

Ans. (b)

8.2.3 Octave Band Analysis

- A noise can be fully characterised by breaking it down into its frequency component called spectra. Normal practice is to consider 8 to 11 octave bands. An octave band is the frequency interval between a given frequency and twice that frequency.
- For example, for a given frequency of 22 Hz, the first octave band is form 22 Hz to 44 Hz.

NOTE

(i) An octave band analysis is done for community noise control and for identifying violators. This is usually provided by one third octave band analysis.

(ii) Instrument design and testing is provided by Narrow band analysis.

8.2.4 Averaging Sound Pressure Levels

The average value of the various recorded sound pressure levels (L_p) at a particular place over a given period cannot be computed by simple averaging due to log scale involved in their values. On the other hand, the following equation is used to compute average pressure level.

Average pressure level $$\bar{L}_p = 20\log\frac{1}{N}\sum_{n=1}^{n=N}(10)^{\frac{Ln}{20}}$$

where, $\bar{L}_p$ = Average sound pressure level in dB_{ro} : 20 μPa

N = Number of measurement readings

L_n = nth sound pressure level in dB_{ro}, 20 μPa

n = 1, 2, 3 ..... N

Say for example, the average of 4 measurement readings recorded as 40, 50, 62 and 72 dB_{ro}: 20 μPa is computed to be 63 dB, in place of straight airthmatic average value of 56 dB as follows

$$\sum_{n=1}^{n=4}(10)^{\frac{L_n}{20}} = \left[(10)^{40/20}+(10)^{50/20}+(10)^{62/20}+(10)^{72/20}\right]$$

$$= [100+316.23+1258.92+3981.07] = 5656.22$$

and $$\bar{L}_p = 20\log_{10}\frac{1}{4}\times 5656.22 = 63 \text{ dB}$$

Example 8.3 Two sources generate noise levels of 90 dB and 94 dB respectively. The cumulative effect of these two noise levels on the human ear is

(a) 184 dB (b) 95.5 dB
(c) 94 dB (d) 92 dB

Ans. (b)

The cumulative effect of these two noise levels will be addition of 90 dB and 94 dB.

$$P_{rms1} = \left(10^{90/20}\right)\times 20 = 632455.532 \ \mu\text{Pa}$$

$$P_{rms2} = \left(10^{94/20}\right)\times 20 = 1002374.47 \ \mu\text{Pa}$$

$$P = \sqrt{P_{rms1}^2 + P_{rms2}^2}$$

$$\text{Cumulative effect} = 20\log\left(\frac{P}{20}\right) = 95.5 \text{ dB}$$

8.3 Noise Rating Systems

A noise may consist of different types of sounds with different pressure levels operating for different time intervals. The combined resultant noise will infact be responsible for determining the human response and degree of annoyance caused by it. The combined impact of different sound pressure lasting for different periods is therefore attempted to be worked out by using some statistical measures, such as L_N and L_{eq} system.

8.3.1 The L_N Concept

The parameter L_N is a statistical measure indicating how frequently a particular sound level is exceeded. The Value of L_N will represent the sound pressure level that will exceed for N% of the gauging time. Say for example, the given 70 dB value of L_{60} will mean that the sound level will exceed 70 dB for 60% of the measuring time.

When L_N is plotted against N (where N = 1, 2, 3 .... 100%) a cumulative distribution curve is obtained as shown in figure 8.2.

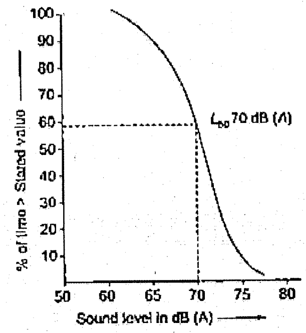


Fig. 8.2 Cumulative Distribution Curve

Example 8.4 What will be the resultant decibel level when two sources make noise of equal decibels?

(a) Decibel level will the same
(b) Decibel level will increase by 3 decibels
(c) Decibel level will decrease by 3 decibels
(d) Decibel level will be equal to the sum of decibels of the two sources

Ans. (b)

8.3.2 The L_{eq} Concept

L_{eq} is defined as the constant noise level which, over a given time, expands the same amount of energy as is expanded by the fluctuating levels over the same line.

This value is expressed as

$$L_{eq} = 10\log_{10}\sum_{i=1}^{i=n}(10)^{\frac{L_i}{10}}\times t_i$$

where, n = total number of sound samples

L_i = The noise level of any i^{th} sample

t_i = Time duration of i^{th}, expressed as fraction of total sample time

Using the above equation, L_{eq} value for fluctuating noise level of 95 minutes (i.e. the one with 60 dB lasting for 10 minutes followed by sound of 60 dB after 80 minute and followed by 100 dB for 5 minutes can be worked out as below.)

$$\sum_{1}^{3}(10)^{\frac{L_i}{10}}\times t_i = \left[(10)^{\frac{90}{10}}\times\frac{10}{95}+(10)^{\frac{60}{10}}\times\frac{80}{95}+(10)^{\frac{100}{10}}\times\frac{5}{95}\right]$$

$$= 1.053\times 10^7 + 0.842\times 10^6 + 0.52632\times 10^7$$

$$= 10^6[10.53+0.84+526.32] = 537.69\times 10^6$$

$$L_{eq} = 10\log_{10}\left(537.69\times 10^6\right) = 87.3 \text{ dB}$$

The above fluctuating sound with its equivalent energy level (L_{eq}) is represented graphically in figure, which reflects that high occasional sounds do influence the resultant equivalent value by a large extent.

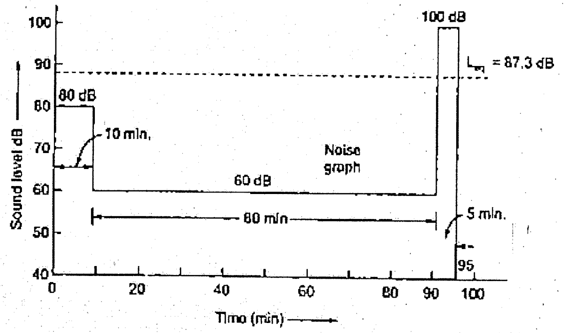


Fig. 8.3 Noise graph and its equivalent noise level

NOTE

The equivalent noise level (L_{eq}) constitutes an important parameter for evaluating the impact of fluctuating noise of all kinds such as from aircraft, street and road traffic, rail traffic industrial machines, sports stadium, play grounds. etc.

8.4 Sources of Noise and Their Noise Levels

Outdoor noise is usually produced by the following sources :

8.4.1 Traffic Noise

Traffic usually produces a lot of noise. The amount and type of noise produced by traffic is largely dependent upon the type of traffic. Noise levels produced by different types of traffic are given table 8.1:

Table: 8.1 Noise Levels of Different Sources of Traffic

S. No.	Source of Noise	Noise level in dB
1.	Air traffic	
	(i) Jet aircraft at take off stage at about 300 m	100-110
	(ii) Propeller type aircraft at take off stage at about 300 m	90-100
2.	Rail traffic (at about 30 m)	90-110
3.	Heavy road traffic (highway)	80-90
4.	Medium road traffic (main streets)	70-80
5.	Light road traffic (side streets)	60-70

8.4.2 Industrial Noise

Noise is the essential by product of industry, its intensity and nature being dependent upon the type of the industry. Industrial noises are usually produced by rotating, reciprocating or any other types of machinery or by high pressure, high velocity gases, liquids or vapour involved in the industrial processes. The usual noise level of the industries is 60 to 95 decibels.

8.4.3 Noise Produced by Other Sources

Several other human activities, such as blaring of loud speakers and sirens, shouting of hawkers, playing of children, general life and activity, ring of temple and church bells, etc. do produce noise of different levels, tones and spectra.

8.5 Noise Abatement and Control

- There are certain noises which can be kept under control by legal laws and ordinances and there are others which have to be damped and attenuated by the use of good technology and town planning.
- The noises produced by automobiles and trains, being the biggest noise nuisance is a modern city life, can be abated by construction of walls on both sides of roads and railways lines.

$$\text{Noise reduction dB} = 10 \log_{10}\left(\frac{20H^2}{\lambda R}\right)$$

where, H = height of the barrier wall
λ = wavelength of sound
D = Distance between barrier and the receiving point

- Raising of such obstructions and barriers in between the noise sources (auto-mobiles) and residences, may considerably reduce the noise levels reaching the residences. Attanuation of up to 15 decibles is possible in this manner. The extent of attenuation achieved by raising of such a barrier well, is shown in figure 8.4. Where $D \geq R$ and $R \gg H$, the noise reduction may also be calculated by the equation.
- Raising of thick and high vegetation and tree growing along sides of roads and railway lines, offer cheaper barriers to cause such noise reduction.
- Noise levels in residential building can be reduced to some extant by offsetting the building from the main or street roads by a suitable distance. The farther is the distance, the better will be the attenuation, because the intensity of noise reduces with increase in distance.

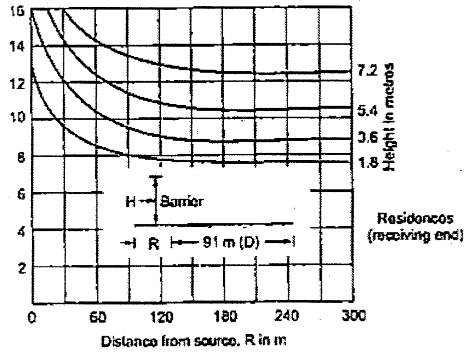


Fig. 8.4 Noise reduction caused by barrier wall raised between a noise source and the receiving end.

Table: 8.2 Acceptable Noise Levels for Residential Areas, as per I.S.code 4958-1968

S. No.	Acceptable outdoor noise levels in residential areas		S. No.	Acceptable indoor noise levels for various types of buildings	
	Location	Noise levels dB(A)		Location	Noise levels dB(A)
1.	Rural areas	25-35	1.	Radio and TV studios	25-35
2.	Suburban areas	30-40	2.	Music rooms	30-35
3.	Urban Residential areas	35-45	3.	Hospitals, class rooms, auditoria	35-40
4.	Residential and business urban areas	40-50	4.	Apartments, hotels, homes Conference-rooms, small offices	35-40
5.	City areas	45-55	5.	Court rooms, private offices, libraries	40-45
6.	Industrial areas	50-60	6.	Large public office, banks stores, etc.	45-50
			7.	Restaurants	50-55

- Another very important method for abating noise effect on mankind is to use proper town planning technique.

Important Expressions

1. Frequency, $(f) = \frac{1}{T}$ where, T = Time period
2. Wave length, $\lambda = C \cdot \frac{1}{f}$ where, C = Velocity of sound wave
3. $P_{rms} = \sqrt{P_{(t)}^2} = \sqrt{\frac{1}{T}\int_0^T P_{(t)}^2\, dt}$ where, $P_{(t)}$ = Pressure at any time t
4. Sound Intensity, $I = \frac{W}{a} = \frac{P_{rms}^2}{\rho \cdot C}$
   where, W = Power of sound in watt, a = A unit area perpendicular to the direction of wave motion, ρ = Density of air or medium (kg/m³)
5. Sound level, $L = \log_{10}\frac{Q}{Q_0}(b)$
6. Sound pressure level, $L_p = 20\log_{10}\left(\frac{P_{rms}}{20\ \mu Pa}\right)$ dB
7. Sound intensity level, $L_I = 10\log_{10}\left(\frac{I}{10^{-12}}\right)$ dB
8. Averaging sound pressure levels, $\bar{L}_p = 20\log\frac{1}{N}\sum_{n=1}^{n=N}(10)^{L_n/20}$
9. $L_{eq} = 10\log\sum_{i=1}^{i=n}(10)^{\frac{L_i}{10}} \times t_i$
10. Noise reduction (dB) $= 10\log_{10}\left(\frac{20H^2}{\lambda R}\right)$
    R = Distance between barrier of the receiving point.

Summary

1. Noise can be defined as that unwanted sound pollutant which produces undesirable physiological and psychological effects.
2. Narrow band analysis $\xrightarrow{\text{done for}}$ Instrument design and testing.
   Octave band analysis $\xrightarrow{\text{done for}}$ Community noise control and identifying violators.

Objective Brain Teasers

Q.1 Which of the following pairs are correctly matched?
1. Reverberation time : Time required to reduce noise by 60 dB
2. NIPTS : Responsible for permanent hearing loss
3. Sound foci convex surface : Formed when sound waves are reflected from convex surface
4. TTS : Responsible for temporary hearing loss

Select the correct answer using the codes given below:
(a) 2, 3 and 4 (b) 1, 3 and 4
(c) 1, 2 and 4 (d) 1, 2 and 3

Q.2 Acoustics of an auditorium is considered to be excellent when its reverberation time is between
(a) 0.50 and 1.50 s (b) 1.50 and 2.00 s
(c) 2.00 and 3.00 s (d) 3.00 and 5.00 s

Q.3 What type of noise can be abated by providing lining on walls and ceiling with sound absorbing materials?
(a) Source noise
(b) Reflection noise
(c) Structural noise
(d) Direct air-borne noise

Q.4 A machine in a steel plate fabricating industry is found to be producing a sound level of 50 dB. In the expansion plans one more such machine needs to be added. What will be the combined noise level?
(a) 80 – 100 dB (b) 101 – 150 dB
(c) 51 – 70 dB (d) 40 – 50 dB

Q.5 For noise measurement, formula for sound pressure level (SPL) is $20\log\frac{P}{P_{ref}}$. What will be the resultant noise in dB if P is 0.0002 μ bar?
(a) 0 (b) 60
(c) 90 (d) 100

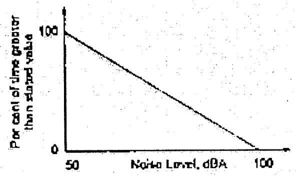
Q.6 Consider the following statements:
1. Noise pollution can be reduced using double-glass window panes.
2. Glass absorbs the noise.
3. The air trapped in the double-glass system acts as an insulator and reduces the noise.
4. The noise totally reflects back due to the two layers of glass.

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 1, 2 and 3 only
(c) 1 and 3 only (d) 2 and 4 only

Q.7 Consider the following statements:
1. Sound is a form of mechanical energy from a vibrating substance, transmitted by a cyclic series of compressions and rarefactions of the molecules of the material through which it passes.
2. In a pure tone, the wave pattern of the alternating positive and negative sound pressure is of ideal sinusoidal form with fixed wave length, frequency and amplitude.
3. The speed of transmission of sound is a function of the transmitting medium and its temperature.
4. The audible range of 200 to 25000 Hz is considered normal for young adults.

Which of these statements are correct in respect of sound transmission?
(a) 1, 2, 3 and 4 (b) 1, 2 and 4 only
(c) 1, 2 and 3 only (d) 2, 3 and 4 only

Q.8 The cumulative noise power distribution curve at a certain location is given below.



The value of L_{40} is equal to
(a) 90 dBA (b) 80 dBA
(c) 70 dBA (d) 60 dBA

Q.9 The reference pressure used in the determination of sound pressure level is
(a) 20 μPa (b) 20 dB
(c) 10 μPa (d) 10 dB

Q.10 According to the Noise Pollution (Regulation and Control) Rules, 2000, of the Ministry of Environment and Forests, India, the day time and night time noise level limits in ambient air for residential area expressed in dB(A) L_{eq} are
(a) 50 and 40 (b) 55 and 45
(c) 65 and 55 (d) 75 and 70

Answers

1. (a)	2. (a)	3. (b)	4. (c)	5. (a)
6. (c)	7. (a)	8. (c)	9. (a)	10. (b)

Hints and Explanations:

Ans.1 (a)

Reverberation time is the time required to reduce the intensity to one-millionth of its initial value.

$$\text{Sound level (dB)} = 10 \log \left(\frac{I_1}{I_2}\right)$$

$$= 10 \log (10^6) = 60 \text{ dB}$$

TTS (Temporary Threshold Shift) is temporary impairment of hearing acuity as indicated by change in the threshold of audibility. PTS (Permanent Threshold Shift) is related to permanent hearing loss. The sound foci are formed when sound waves are reflected from concave surface.

Ans.2 (a)

For excellent acoustic conditions, reverberation time should be between 0.5 to 1.5 seconds.

Ans.3 (b)

Sound absorbing materials does not reflect the noise and they are mostly used in theatres etc.

Ans.4 (c)

The sound pressure level in dB is given by

$$L_p = 20 \log_{10}\left(\frac{p_{rms}}{20\ \mu\text{Pa}}\right)$$

Sound level of 1st machine = 50 dB

$$\therefore \quad 50 = 20 \log_{10}\left(\frac{p_{rms}}{20\ \mu\text{Pa}}\right)$$

$$\Rightarrow \quad \frac{p_{rms}}{20\ \mu\text{Pa}} = \text{Antilog}\left(\frac{50}{20}\right)$$

$$\Rightarrow \quad p_{rms} = 6324.55\ \mu\text{Pa}$$

Since the sound level of 2nd machine is also 50 dB, therefore p_{rms} of 2nd machine will also be 6324.55 μPa.

∴ Resultant sound level in rms

$$= \sqrt{(6324.55)^2 + (6324.55)^2} = 8944.26\ \mu\text{Pa}$$

$$\therefore \quad L_p = 20\log_{10}\left(\frac{8944.26}{20}\right)$$

$$= 53.01 \text{ dB}$$

Ans.5 (a)

$$SPL = 20 \log_{10}\left(\frac{P}{P_{ref}}\right)$$

$$P_{ref} = 20\ \mu\text{Pa}$$

$$P = 0.0002\ \mu\text{ bar}$$

$$= 0.0002 \times 10^5\ \mu\text{Pa}$$

$$\therefore \quad SPL = 20\log_{10}\left(\frac{0.0002 \times 10^5}{20}\right)$$

$$= 20\log_{10}(1) = 0$$

Ans.8 (c)

L_{40} is the sound pressure level in dB which is exceeded for 40% of the gauging time.

$$\text{Now, slope of the given curve} = \frac{100-0}{100-50} = 2$$

∵ Curve is a straight line, hence slope is constant

$$\therefore \quad 2 = \frac{40-0}{L_{40}-50}$$

$$\Rightarrow \quad L_{40} - 50 = 20$$

$$\Rightarrow \quad L_{40} = 70 \text{ dB}$$

Ans.9 (a)

The sound pressure of the faintest sound that can be heard by a normal healthy individual is about 20 μPa. Hence, this pressure is used as reference pressure in determination of sound pressure level.

Ans.10 (b)

Ambient air quality standards in respect of Noise as per Noise Pollution (Regulation and Control) Rules, 2000, of the Ministry of Environment and Forests, India are tabulated below:

Category of Area/Zone	Day time	Night time
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45
Silence Zone	50	40

■■■■