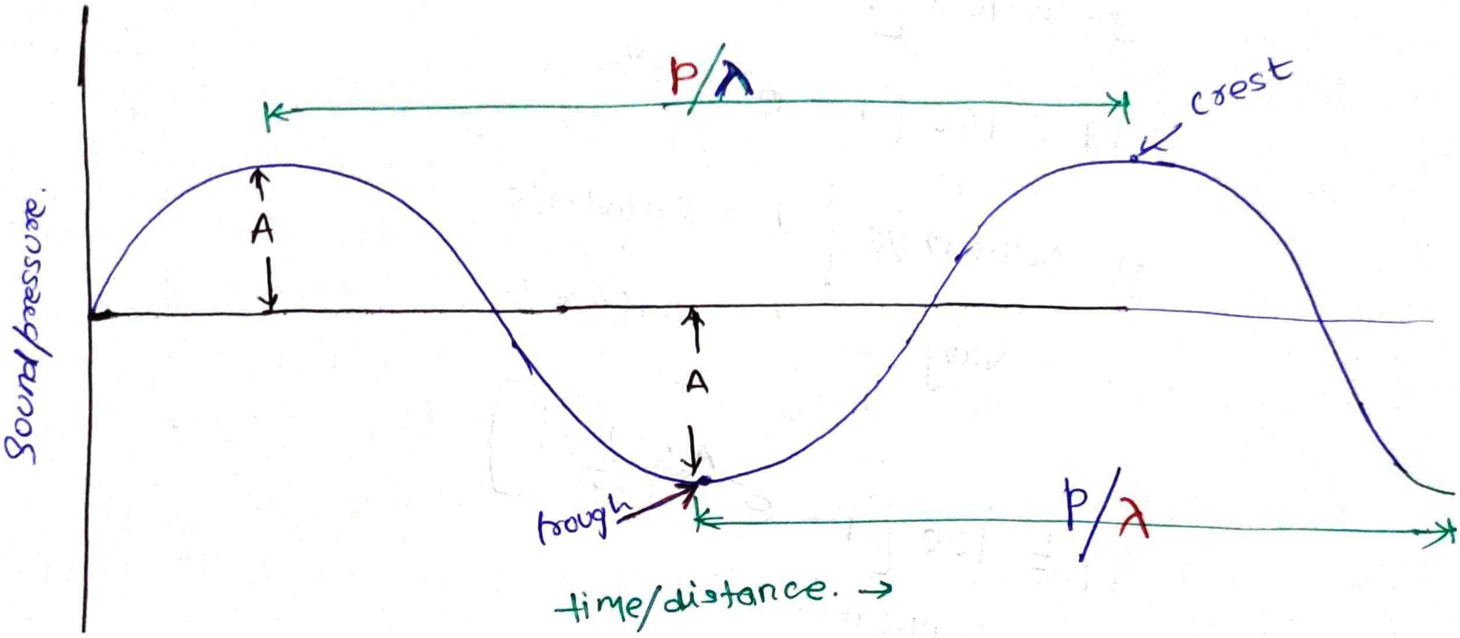
Noise Pollution

→ Presence of one or more sound in such duration at such pressure level and at such frequency that the life in biosphere gets effected is termed as noise pollution.

Properties of sound and its measurement.

→ Sound in any medium propogates/travels in the form of pressure waves undergoing compression and rarefraction/expansion.



(i) Time period.

Time between two succesive crest or trough is termed as time period,

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

(ii) Wave length (λ)

Distance between two succesive crest or trough is termed as wave length.

$$\lambda = cp$$

$$\lambda = \frac{c}{f}$$

$$\boxed{c = \lambda f}$$

c = velocity of sound wave.

(iii) Amplitude.

It is maximum or minimum pressure over or below the mean pressure. ($\bar{p}=0$) is termed as amplitude.

Note:- All the sound measuring devices are designed to give root mean square pressure.

$$p_{rms} = \sqrt{\overline{p^2_{(t)}}}$$

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

$P_{(t)}$ = pressure at any time t.

$$\left[\sigma = \sqrt{\frac{\Sigma (x_i-\bar{x})^2}{N}} = \sqrt{\int_0^T \frac{(P_{(t)}-0)^2}{T}} = \sqrt{\frac{1}{T}\int_0^T P^2_{(t)} dt} \right]$$

Q If $P_{(t)} = A\sin\omega t$, find p_{rms} = ??

$$p_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} A^2 \sin^2 \omega t \, dt} = \frac{A}{\sqrt{2}}$$

(iv) Power of Sound (w)

It is defined as the rate of work done by travelling sound wave in the direction of propogation of wave or it is the energy transmitted by a sound wave in direction of its propogation.

(v) Sound Intensity (I)

It is defined as the sound power averaged over the time per unit area normal to the direction of propogation of sound wave.

$$I = \frac{W}{a} \ (\text{watt}/m^2)$$

w = power of sound (watt)

a = area ⊥r to direction of propogation of sound wave (m^2)

Note (i) Intensity of sound, $I = \frac{p_{rms}^2}{\rho c}$

ρ = density of air (of given medium)
c = velocity of sound wave)

$[I \propto p_{rms}^2]$

(ii) Smallest level of noise that can be heard by human ear is $20\,\mu Pa$ and highest may extend upto 200 Pa.

Level of Noise.

Level of noise of any given sound pressure is always measured wrt standard reference sound pressure.

$$L = \log_{10} \frac{Q}{Q_0} \quad \text{(Bels)}$$

Q = Measured quantity of sound pressure (P) or sound Intensity I.

Q_0 = Reference standard quantity of sound pressure, (P_0) or sound Intensity.

$$L = 10 \log_{10} \left(\frac{Q}{Q_0}\right) \quad \text{(dB)}$$

[1 Bel = 10 dB]

Case-I Sound Intensity level (L_i)

$$L_i = 10 \log_{10} \left(\frac{I}{I_0}\right) \text{ dB}$$

here, $I_0 = 10^{-12}\ W/m^2$.

Case-II Sound pressure level. (L_p)

$$L_p = 10 \log_{10} \left(\frac{P_{rms}}{P_{rms_0}}\right)^2$$

$$L_p = 20\log_{10}\left(\frac{p_{rms}}{p_{rms_0}}\right) \quad (dB)$$

Here, $p_{rms_0} = 20\mu Pa$.

[1 Bar = 10^5 N/m^2]

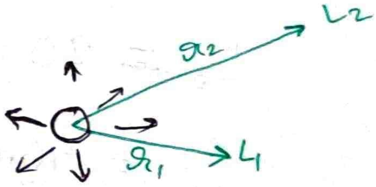
Note: An increase in 20dB in sound pressure level will correspond to sound pressure or loudness of sound increasing by 10 times.

→ 1 dB is the faintest sound which can be heard by human ear and maximum can be tolerated upto 180 dB.

Note: (i) In real medium, level of varies as follow :-

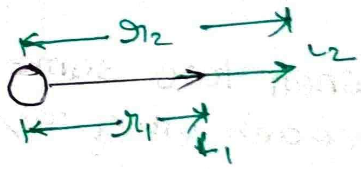
(i) For point source.

$$L_2 = L_1 - 20\log_{10}\left(\frac{r_2}{r_1}\right)$$



(ii) for linear source

$$L_2 = L_1 - 10\log_{10}\left(\frac{r_2}{r_1}\right)$$



(ii) Addition of two different level of noise is not simple arithmetic addition due to the involvement of log scale.

eg. 20 dB + 40 dB ≠ 60 dB.

$E \propto p_{rms}^2$

$E_r = E_1 + E_2$

$K\, p_{rms_r}^2 = K\, p_{rms_1}^2 + K\, p_{rms_2}^2$

$p_{rms_r} = \sqrt{p_{rms_1}^2 + p_{rms_2}^2}$

$\Rightarrow L_r = 20\log_{10}\left(\frac{p_{rms_r}}{20\mu Pa}\right)$ dB

Q

~~20 d40~~

$L_1 = 20dB = 20\log_{10} \frac{P_{rms_1}}{20\mu Pa}$.

$P_{rms_1} = 200 \mu Pa$.

$L_2 = 40dB = 20\log_{10} \frac{P_{rms_2}}{20\mu Pa}$.

$P_{rms_2} = 2000 \mu Pa$.

$$P_{rms_r} = \sqrt{P_{rms_1}^2 + P_{rms_2}^2}$$

$$= \sqrt{200^2 + 2000^2}$$

$$= 2009.9 \mu Pa.$$

$$L_r = 20\log_{10}\left(\frac{2009.9}{20}\right)$$

$$= 40.04 dB.$$

Note ③ when two same sound pressure level are added with each other resultant is increased by "3dB"

$L_r = L + L$

$L_r = L + 3$

$L = 20\log_{10} \frac{P_{rms}}{20\mu Pa}$ ⇒ $P_{rms} = x \mu Pa$.

$P_{rms_r} = \sqrt{P_{rms}^2 + P_{rms}^2} = \sqrt{2}\, P_{rms}$

$L_r = 20\log_{10} \frac{\sqrt{2}\, P_{rms}}{20\mu Pa}$.

$= 20\log_{10}\sqrt{2} + 20\log_{10} \frac{P_{rms}}{20\mu Pa}$.

$L_r = 3 + L$

eg. 20 dB + 20 dB = 23 dB

eg. 100 dB + 100 dB = 103 dB

eg. 50 dB + 50 dB + 50 dB + 50 dB = 56 dB

eg. 20 dB + 40 dB = 40 dB — 43 dB

eg. 10 dB + 20 dB + 50 dB + 80 dB + 100 dB = 100 − 103 dB

20−23 dB

50−53 dB

80−83 dB

100−103 dB

Note: Average of different sound level is not the simple arithmetic average due to the involvement of log scale.

$$L_{avg} = 20\log_{10} \frac{1}{N}\Sigma (10)^{L_i/20}$$

eg: 20 dB, 40 dB, 80 dB, 100 dB.

~~$\frac{20+40+80+100}{4}$~~

$$L_{avg} = 20\log_{10} \times \frac{1}{4}\left[10^{20/20} + 10^{40/20} + 10^{80/20} + 10^{100/20}\right]$$

$= 88.8$ dB.

Or

$$L_{avg} = 20\log_{10} \frac{1}{4}\left[10^1 + 10^2 + 10^4 + 10^5\right]$$

$x + 10^5$ $\qquad x < 10^5$

$$L_{avg} = 20\log_{10} \frac{1}{4}\left[10^{100/20}\right]$$

$$= 20\log_{10}\left[10^5/4\right]$$

$$= 20\left[\log_{10} 10^5 + \log_{10} \tfrac{1}{4}\right]$$

$$= 20[5 - 2\log 2]$$

$$= 20[5 - 2 \times 0.3010] = 87.96$$

Note 5. Ambient air quality standard w.r.t. to noise as per EPA.

Area Code	Category of Area zone	Limits in dB (L_{eq})	
		Day time	Night time
A	Industrial area	75	70
B	Commercial Area	65	55
C	Residential area	55	45
D	Silence.	50	40

Note 6: In order to reduce the noise pollution obstruction and barrier between the noise source and point of impact can be constructed which reduces the noise level given as follows:-

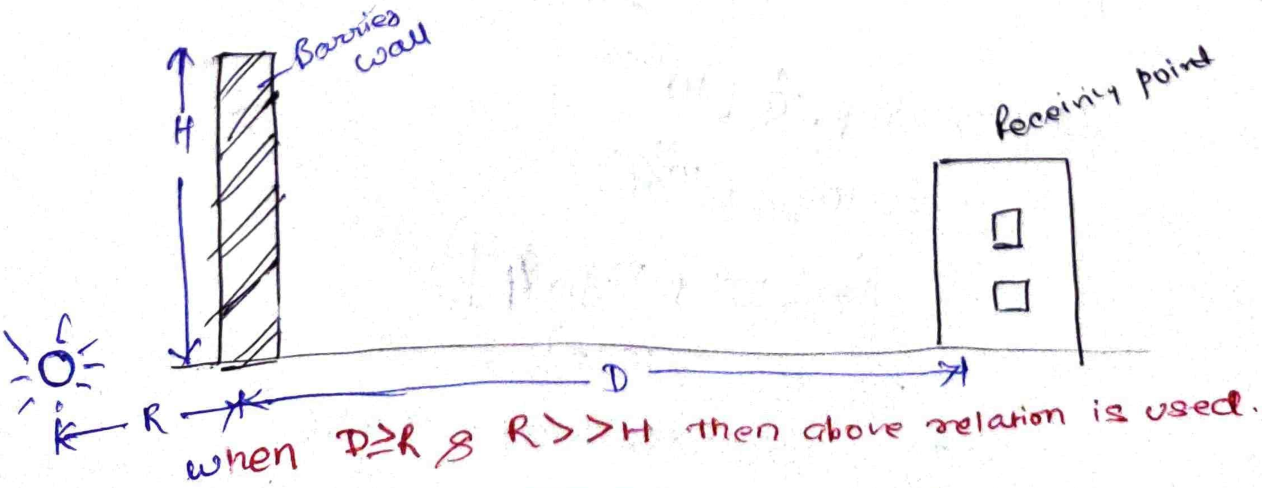
$$\text{Noise reduction (dB)} = 10 \log_{10}\left(\frac{20H^2}{\lambda R}\right)$$

R = Distance of barrier wall from the source in (m)

H = Height of barrier wall.

λ = wave length of sound.

D = distance between barrier and receiving point



when $D \geq R$ & $R >> H$ then above relation is used.

Rating of Noise.

As different types of noise exist in the system at different pressure level at different frequency and for different duration in order to find their resultant effect. rating of noise is done by any of the following method.

(i) Lequivalent Concept (L_{eq})

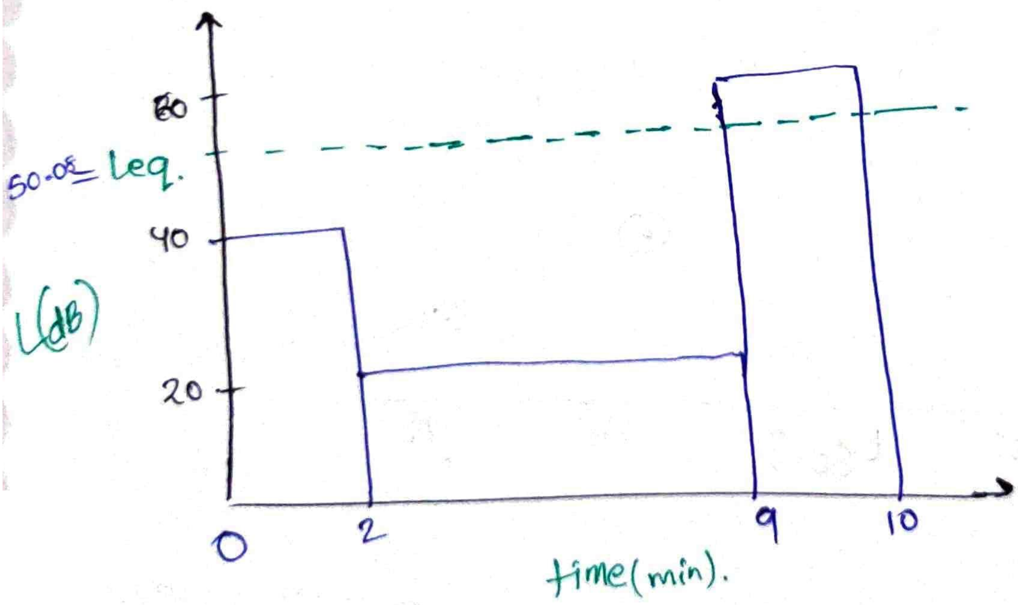
It is the constant sound pressure level which over a given time expand the same amount of energy as is being expanded by fluctuating sound pressure level in same time

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

n = total no. of sound sample.

L_i = given sound level sample.

t_i = time duration of ith sample of sound, expressed in terms of total time.



$$L_{eq} = 10 \log_{10} \left(10^{40/10} \times \frac{2\text{ min}}{10} + 10^{20/10} \times \frac{7}{10} + 10^{60/10} \times \frac{1}{10} \right)$$

$L_{eq} = 50.088$ dB

(ii) L_N Concept

L_n represents the sound pressure level that is exceeded for N% of gauging time.

eg

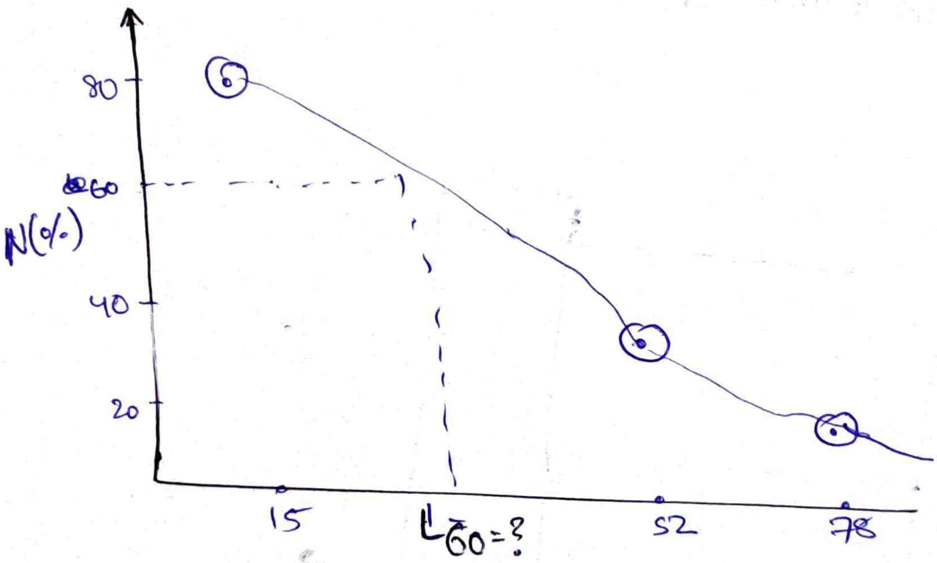
	L (dB)	Arrange in descending
1.	80	100
2.	78	80
3.	100	78
4.	5	65
5.	15	52
6.	24	48
7.	36	36
8.	48	24
9.	52	15
10.	65	5

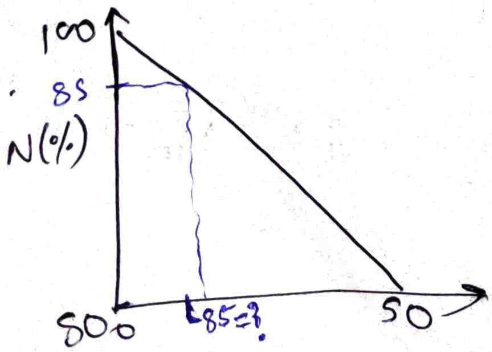
$L_N = x$ dB

eg $L_{20} = 70$ dB

$L_{40} = 52$ dB

$L_{80} = 15$ dB





$L_{85} = ?$

$$\frac{100-85}{L_{85}-0} = \frac{100-80}{50-0}$$

$L_{85} =$ ~~12.5 dB~~

$= 37.5$ dB