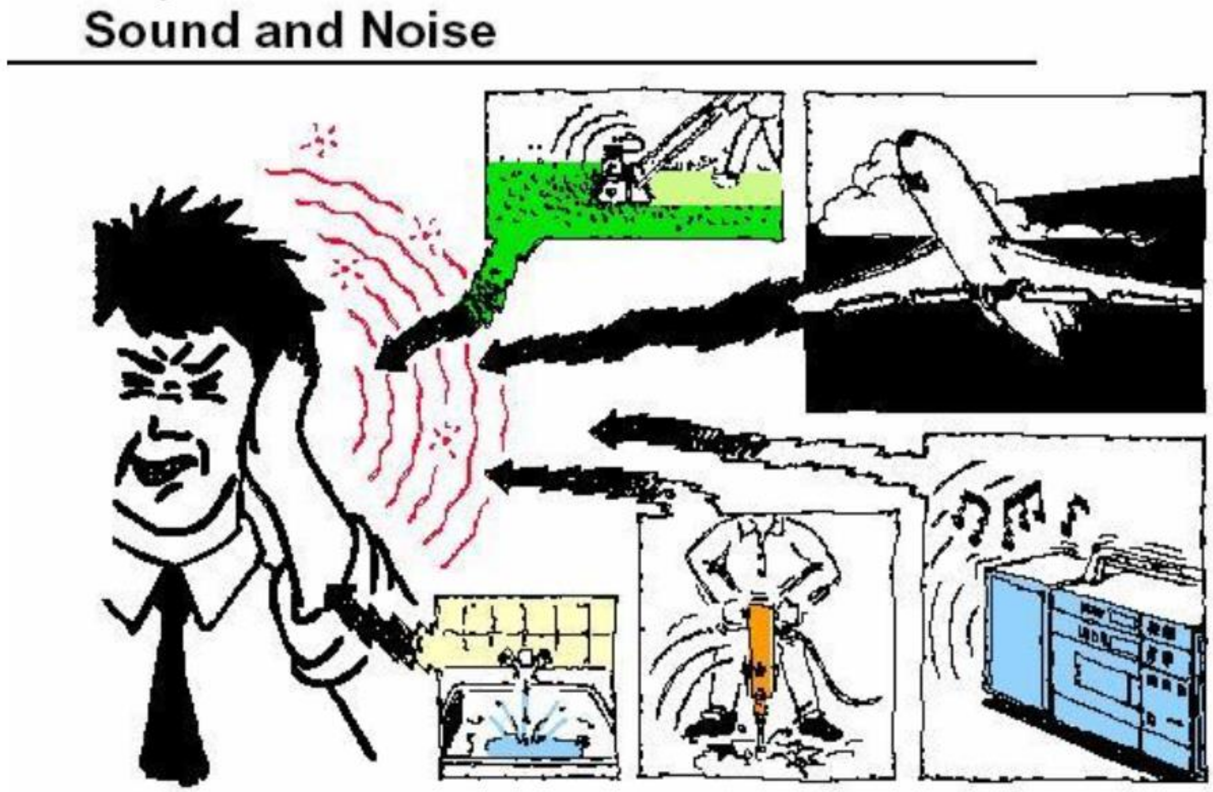
FUNDAMENTALS OF NOISE

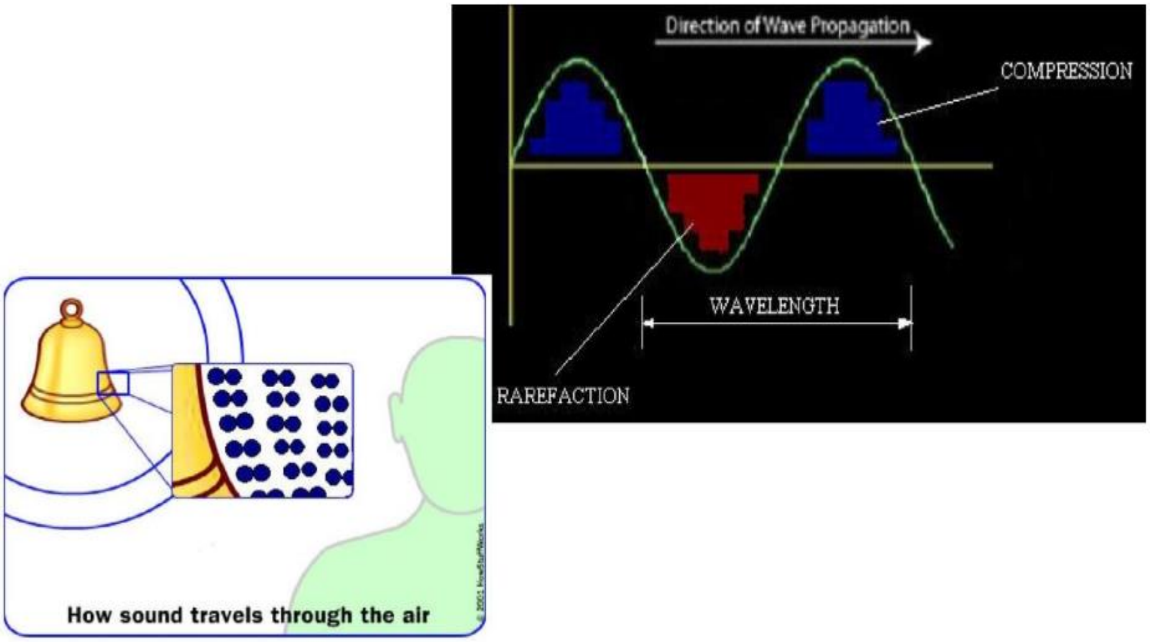
Sound is a sensation of acoustic waves (disturbance/pressure fluctuations setup in a medium)

Unpleasant, unwanted, disturbing sound is generally treated as Noise and is a highly subjective feeling

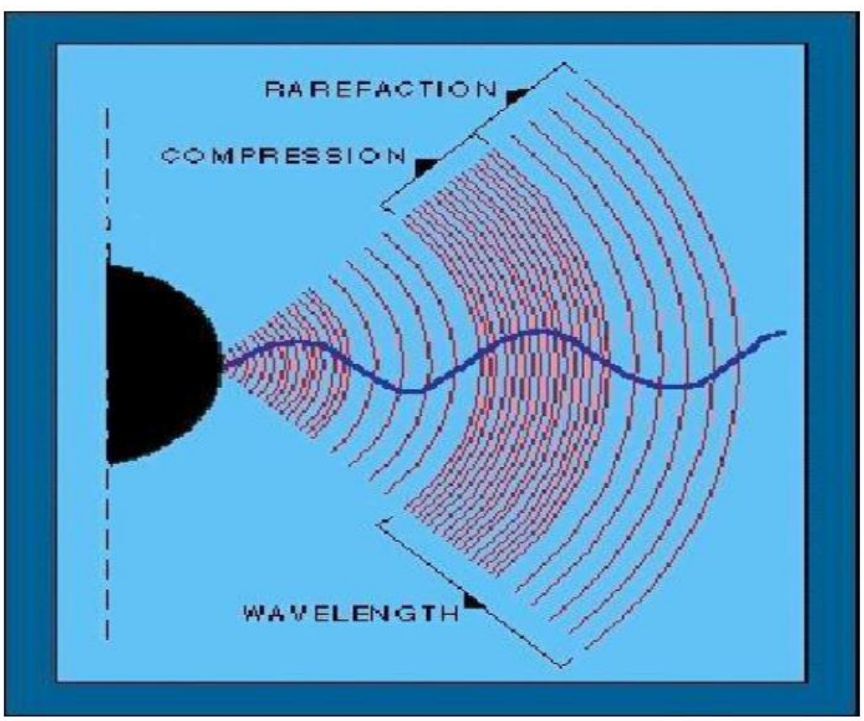


- Sound is a disturbance that propagates through a medium having properties of inertia (mass) and elasticity. The medium by which the audible waves are transmitted is air.

Basically sound propagation is simply the molecular transfer of motional energy. Hence it cannot pass through vacuum.



The disturbance gradually diminishes as it travels outwards since the initial amount of energy is gradually spreading over a wider area. If the disturbance is confined to one dimension (tube / thin rod), it does not diminish as it travels (except loses at the walls of the tube)



Sound Measurement

- Provides definite quantities that describe and rate sound
- Permit precise, scientific analysis of annoying sound (objective means for comparison)
- Help estimate Damage to Hearing
- Powerful diagnostic tool for noise reduction program: Airports, Factories, Homes, Recording studios, Highways, etc.
  - Quantifying Sound

Acoustic Variables: Pressure and Particle Velocity

<u>Root Mean Square Value (RMS) of Sound Pressure</u>

Mean energy associated with sound waves is its fundamental feature energy is proportional to square of amplitude

$$\bar{p} = \left[\frac{1}{T} \int_0^T [p(t)]^2 \, dt \right]^{\frac{1}{2}}$$

$$p = 0.707a$$

RANGE OF PRESSURE

Range of RMS pressure fluctuations that a human ear can detect extends from

0.00002 N/m^2 (threshold of hearing) to

20 N/m^2 (sensation of pain)

1000000 times larger

Atmospheric Pressure is $10^5 N/m^2$

so the peak pressure associated with loudest sound is 3500 times smaller than atm.pressure

The large range of associated pressure is one of the reasons we need alternate scale

dB SCALE

The ear has the remarkable ability to handle an enormous range of sound levels. In order to express levels of sound meaningfully in numbers that are more manageable, a logarithmic scale is used, rather than a linear one. This scale is the decibel scale.

What is a decibel? Zero decibels (0 dB) is the quietest sound audible to a healthy human ear. From there, every increase of 3 dB represents a doubling of sound intensity, or acoustic power.

Loudness and Sound Intensity (Power)

The relative loudness that we perceive is a subjective psychological phenomenon, not something that can be objectively measured. Most of us perceive one sound to be twice as loud as another one when they are about 10 dB apart; for instance, a 60-dB air conditioner will sound twice as loud as a 50-dB refrigerator. Yet that 10-dB difference represents a tenfold increase in intensity. A 70-dB dishwasher will sound about four times as loud as the 50-dB refrigerator, but in terms of acoustic intensity, the sound it makes is 100 times as powerful.

Here's another way of looking at it: If the sound from one typewriter registers 60 dB, then ten typewriters clacking away would register 70 dB (not 600 dB!), and they would sound only twice as loud as one typewriter. You would need 100 typewriters to reach a noise level of 80 dB, and together they would sound only four times as loud as a single typewriter.

Sound Level	Sound Intensity (Power)	Perceived Loudness
60 dB	1x	1y
70 dB	10x	2y
80 dB	100x	4y

The potential for a sound to damage our hearing is proportional to its intensity, not its loudness. That's why it's misleading to rely on our subjective perception of loudness as an indication of the risk to our hearing. See this chart for safe noise exposure limits.

A-weighting (dBA) and C-weighting (dBC)

You will often see noise levels given in dBA (A-weighted sound levels) instead of dB. Measurements in dBA, or dB(A) as it is sometimes written, are decibel scale readings that have been adjusted to attempt to take into account the varying sensitivity of the human ear to different frequencies of sound. (The main effect of the adjustment is that low and very high frequencies are given less weight than on the standard decibel scale.) Many regulatory noise limits are specified in terms of dBA, based on the belief that dBA is better correlated with the relative risk of noise-induced hearing loss.

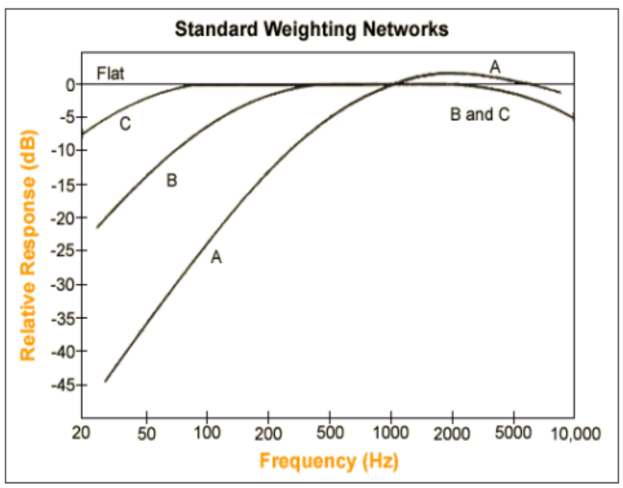


Image courtesy of US Department of Labor

Compared with dB, A-weighted measurements underestimate the perceived loudness, annoyance factor, and stress-inducing capability of noises with low frequency components, especially at moderate and high volumes of noise.*

Another system of adjustment is C-weighting, the dBC scale. dBC is sometimes used for specifying peak or impact noise levels, such as gunfire. Unweighted dB readings are also used for this purpose; there is usually not much difference between the two.

Phons and Sones

The phon is a non-standard noise unit that is designed to reflect perceived loudness, and is based on psychoacoustic experiments in which volunteers were asked to adjust the decibel level of a reference tone of 1 kHz until it was the same loudness as the signal being measured. So for example, if a sound is 70 phons, that means it sounds as loud as a 70-dB, 1-kHz tone. The dBA scale is now widely used instead of phons.

The sone is another non-standard, psychoacoustic unit of loudness. By definition, 1 sone = 40 phons, and from there upward, the sone measurement doubles for every increase of 10 phons:

Phons	40	50	60	70	80	90	100	110	120
Sones	1	2	4	8	16	32	64	128	256

The sone is a more intuitive measure of loudness, because a doubling in the number of sones represents a doubling in perceived loudness (unlike the logarithmic phon scale). Noise levels of household fans are often measured in sones.

Measuring Sound Levels

A sound level meter is the instrument normally used to measure noise levels on the decibel scale. Several factors affect the noise level reading:

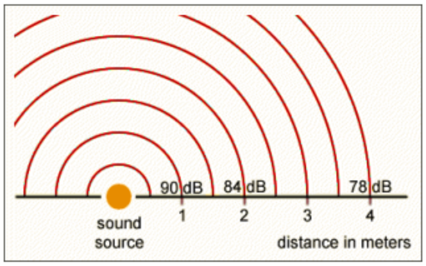


Image courtesy of US Department of Labor

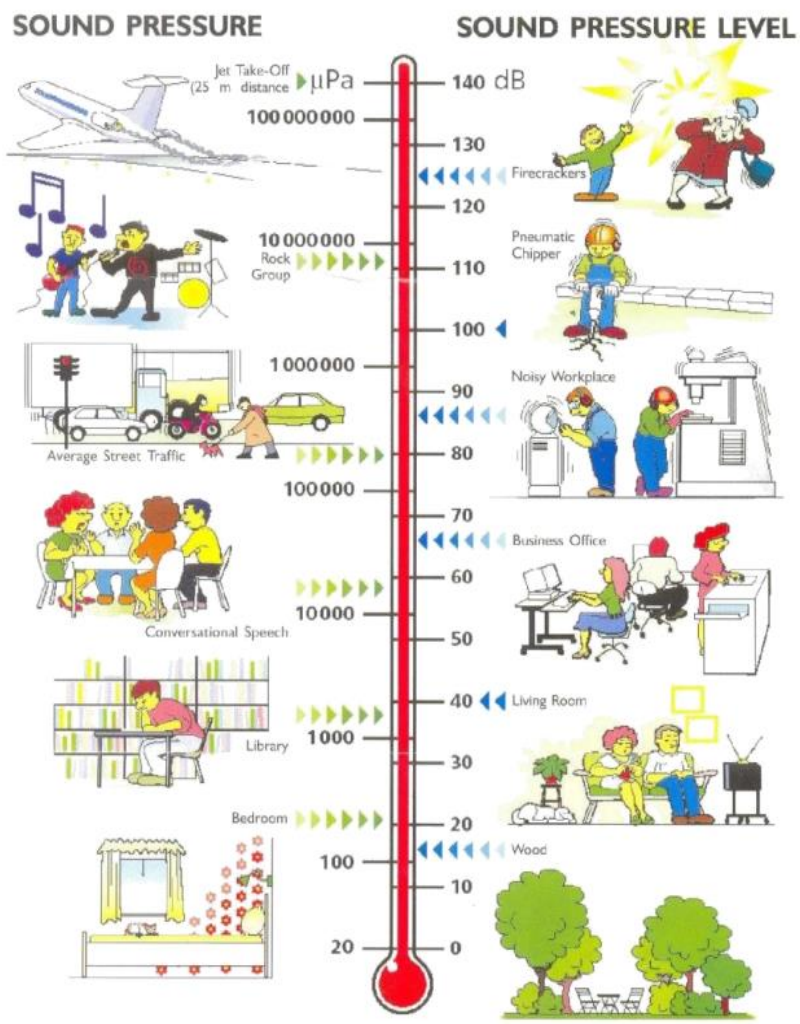
- The distance between the meter and the source of the sound
- The direction the noise source is facing, relative to the meter
- Whether the measurement is taken outdoors (where noise can dissipate) or indoors (where noise can reverberate) For a reported sound level value to be most useful, it is necessary to specify the conditions under which the reading was taken, especially the distance from the source.

Sound Pressure Level

SOUND LEVEL METERS

Description

The electrical signal from the transducer is fed to the pre-amplifier of the sound level meter and, if needed, a weighted filter over a specified range of frequencies. Further amplification prepares the signal either for output to other instruments such as a tape recorder or for rectification and direct reading on the meter.



The rectifier gives the RMS value of the signal. The RMS signal is then exponentially averaged using a time constant of 0.1 s ("FAST") or 1 s ("SLOW") and the result is displayed digitally or on an analog meter.

In some cases, the sound level meter does not include a logarithmic converter. The scale on the indicating device is then exponential so that the linear signal may be read in dB. In this case, the dynamic range of the display is usually restricted to 10 to 16 dB and the precision of the reading is rather poor. In the case of intermittent noise, the user must constantly adjust the amplifier to adapt the output signal to the dynamic range of the display.

When a log converter is used, the display scale is linear in dB and its dynamic range is usually much greater. This type of display has the advantage of providing the same precision at any level and permitting a much better appreciation of the range of fluctuations of the noise to be measured. In this regard, digital displays are less useful.

The specifications of sound level meters are given in IEC 60651 for four types 0, 1, 2, 3 differing by the measurement precision. The measurement precision is reduced as the type number increases, affecting manufacturing costs significantly. The IEC 60651 standard specifies the following characteristics:

- directional characteristics
- frequency weighting characteristics
- time weighting, detector and indicator characteristics sensitivity to various environments.

The type 0 sound level meter is intended as a laboratory reference standard. Type 1 is intended especially for laboratory use, and for field use where the acoustical environment has to be closely specified and controlled. The type 2 sound level meter is suitable for general field applications. Type 3 is intended primarily for field noise survey applications. The frequency response for all types is defined from 10 Hz to 20000 Hz with a higher accuracy at frequencies from 100 Hz to 8000 Hz.

Type 2 and type 3 sound level meters usually include only the A-weighting network and the FAST and SLOW response. Models with AC outlets should be chosen as they make it possible to record the noise on a magnetic tape recorder for further analysis. They are usually equipped with a diffuse field piezoelectric or electret microphone.

Type 0 and 1 sound level meters are often much more versatile with the possibility of measuring vibrations or inserting octave or one third octave band filters. They usually make it possible to measure a non-weighted signal (FLAT response) as well as an A-weighted and a C-weighted signal. They come with a choice from a variety of condenser microphones of different sensitivities and characteristics.

As previously seen, the evaluation of impulses involves the determination of the peak level and the duration of the impulse. Some precision sound level meters are equipped with a circuit that makes it possible to measure the peak level: the time constant used in this case is about 50ms and a circuit is included to hold the instantaneous level. After recording the peak value, the meter must be reset in order to read another value.

Some sound level meters offer the possibility to measure the equivalent A-weighted level $L_{Aeq,T}$ according to the equal energy principle. This can be done in two ways. In the first, the integrating period is prefixed (in some cases, 60 seconds) and the instrument computes the $L_{Aeq,T}$ level progressively: intermediary readings are then irrelevant and the user may only record the final value. In the second type, the integrating period is not fixed and the instrument actually gives the $L_{Aeq,T}$ level computed during the time elapsed since it was started. This type is of more use than the first one as the user does not have to define before hand the integrating time to be used. A different type of integrating sound level meter will be more thoroughly discussed in section 6.5.

(Editors‘ note: The International Standards IEC 60651 and 60804 define classes of instruments instead of types. The ongoing revision of these standards will result in one single standard which will define only classes 1 and 2 for normal and integrating sound level meters as well.)

Use of Sound Level Meters

This section describes how to use physically the instrument in order to correctly measure the noise level existing at the point where the microphone is placed. The following steps must be taken successively:

1. Batteries must be checked before use (see Section 6.9) and during long measuring sessions.
2. A wind shield must be used if the air velocity is noticeable. It should anyway be used all the time as a dust shield (see Section 6.9).
3. The microphone should be oriented as described previously.
4. All intruding objects such as the body of the sound level meter (SLM) or the operator itself will degrade the frequency response of the microphone at high frequencies and directivity effects will appear at much smaller frequencies. Therefore, the SLM should be, whenever possible, installed on a stable and sturdy tripod equipped with resilient blocks to isolate the sound level meter from vibration and consequent spurious readings. The operator should be at a reasonable distance (2-3 m) behind the sound level metert. Extension cables should be used if possible when measurements are to be made in a restricted area (see section 6.9). When the instrument makes it possible, an extension rod should be used for the microphone. For walk-through surveys, the SLM should be held well away from the body.
5. The SLM must be calibrated before any measuring session using a calibrator described in Section 6.8. If the temperature of the instrument is significantly different from the ambient temperature where it will be used, it should be first warmed up (see Section 6.9) before calibration and use. The calibration must be checked at the end of the session. If the instrument is not calibrated anymore, the data might have to be discarded and the reasons for this calibration change should be investigated as this might indicate an important malfunctioning of the instrument.

6. Nowadays, it is much more advantageous to use an integrating sound level meter to determine the $L_{Aeq,T}$ over a representative period of time T than to use a simple SLM on fast or slow giving an instantaneous value.