BASIC SOUND PRINCIPLES

SOUND

Any **sound**, whatever it might be, is caused by something vibrating. Without vibration there can be no sound. The vibrating body causes the air particles next to it to vibrate; those air particles, in turn, cause the particles next to them to vibrate. In this way a disturbance of the air moves out from the source of the sound and may eventually reach the ears of a listener. When we hear a sound, air vibrates against our eardrums causing them to vibrate also. These vibrations are detected and analysed by our brains. Although it is usually air that acts as the transmitting medium, sound can be transmitted by other media, e.g. water, building structures.

SOUND WAVES

Sound does not consist of air moving towards us in bulk; it travels through the air as a **sound wave**. A sound wave consists of a disturbance moving out from a source to surrounding places with the result that energy is transferred from one place to another. As the wave passes, the disturbance of particles is in the direction of the wave travel. The displacement of particles of the medium results in alternate regions of high particle density and low particle density. Regions of high particle density are called compressions. Regions of low particle density are called rarefactions. Rarefactions and compressions both move in the direction of the wave travel. The particles of the medium do *not* move bodily in the direction of the wave movement; they vibrate about their normal positions. Each complete vibration of a particle is called a **Cycle** i.e. from its starting position, to a maximum distance in one direction, back through the starting position, then to a maximum displacement in the opposite direction and back to the starting place.

FREQUENCY

The number of cycles completed in one second is called the **frequency** of the vibration. One of the most noticeable differences between two sounds is a difference in pitch. It is the frequency of a sound that mostly determines its pitch.
Frequency is measured in hertz, one **hertz (Hz)** being one cycle per second. (One thousand hertz = 1 kilohertz = 1 kHz.) A high frequency vibration produces a high pitched note; a low frequency vibration gives a low pitched note.
The human hearing range (audible range) is about 20Hz to 20kHz. Though in reality this is less. The frequencies of notes that can be played on a piano range from 27.5 Hz to just over 4kHz.

TIMBRE

Any note played on a piano will sound different to a note of the same pitch produced by another type of instrument, e.g. a tuning fork.
The musical note produced by a tuning fork is called a **pure tone** because it consists of a tone of one frequency. A note played on a piano, or most other instruments, consists of several such tones all sounding together at different frequencies. These frequencies are related to the frequency (usually the lowest one) which gives the note its characteristic pitch. The tone with the lowest frequency is called the **fundamental**. The other tones are called **overtones** If the overtones have frequencies that are whole number multiples (x2, x3...up to x14) of the fundamental frequency they are called **harmonics**. It is the difference in the harmonic content of notes that gives each musical instrument its characteristic sound or **timbre** ("tam-brah"). Therefore although the highest note of a piano has a fundamental frequency of just over 4kHz, equipment used to record music must be able to handle much higher frequencies to preserve the harmonics associated with each note.

TRANSIENTS

Sounds produced by percussive effects are particularly rich in high harmonics. These occur mainly at the start of a sound, e.g. when a stringed instrument is plucked or a cymbal is struck. These **starting transients** are also characteristic of the instrument producing them. Sound equipment must be able to cope with these high frequencies otherwise the tonal quality of the sounds will be altered. Cymbals, for example, can produce frequencies around 20kHz to 25kHz.

PERIODIC MOTION

There are two types of sound; sound of definite pitch, which musicians call a note and sound with no definite pitch, which is a noise. "Music" involves not only notes (of definite pitch) but also much noise as well, e.g. percussion. Noise is an integral part of much music. The difference between a note and a noise is obvious to the ear but what causes the difference? A note consists of regular vibrations; a noise consists of irregular vibrations. **Periodic motion** is movement that is regular and repeating eg. the to-and-fro or oscillation of a pendulum. A musical note is produced by periodic motion at an audible frequency. Non-periodic motion is perceived as a noise.

PHASE.

Particles vibrating due to the passage of a wave are said to be **in phase** if they are moving in the same direction and have the same displacement (i.e. are the same distances from their starting positions).

WAVELENGTH

A **wavefront** is a surface on which all the particles are in the same phase of vibration. The distance between successive wavefronts is called the **wavelength** of the sound. Looked at in terms of compressions and rarefactions the wavelength is the distance between adjacent centres of compression or adjacent centres of rarefaction. Wavelength is important to a sound engineer. The dimensions of a room or even a microphone can affect sound waves, if the wavelength of the sound is similar to those dimensions.

AMPLITUDE & LOUDNESS

A loud sound (note or noise) is produced by vibrations more violent than those producing a soft sound. The more violent vibration is said to have a greater amplitude. The **amplitude** of a wave is the maximum displacement of the vibrating particles from their undisturbed positions. The greater the amplitude of a wave, the greater will be the energy of the vibrating particles and the sound will be more **intense**. As a sound wave travels out from the source, energy is transferred from one vibrating particle to the next. Energy is gradually dissipated in the form of heat so the intensity of the sound decreases as the distance from the source increases. The intensity of the sound is said to be inversely proportional to the distance from the source. The decrease obeys an inverse law (the inverse square law).
At twice the distance from a source the intensity of sound drops to one quarter. At four times the distance it drops to one sixteenth, e.t.c. So moving a microphone may have a greater effect than might be supposed. When a listener moves away from a sound source the sound level does not appear to drop by such proportions. This is because the **ear** has a built in compensating mechanism. The ear drum is connected to the inner ear by a system of three levers. The positions of the pivots of these levers can be changed to provide greater or lesser leverage. Adjustment allows weak sounds to reach the inner ear with maximum strength while loud sounds are reduced to prevent damage to the inner ear. A listener moving twice as far away from a loudspeaker would not experience a decrease in loudness to one quarter. However the (measurable) intensity of the sound would have decreased to that extent. **Loudness** then, is the magnitude of the *sensation* experienced by someone hearing a sound. Intensity is a measurable, physical quantity. Loudness depends not only on the intensity of a sound but also the sensitivity of the listener's ears.

REINFORCEMENT & CANCELLATION

The crowding of particles together causes the pressure of the air to be greater than normal. The pressure is therefore a maximum in the regions of compression and a minimum in the regions of rarefaction. Still air, undisturbed by a sound wave, has a fairly uniform pressure. If two identical sound waves arrive at the same place at the same time the regions of high pressure will coincide and so will the regions of low pressure. This will result in a single wave of greater intensity. The two waves are said to reinforce each other and the phenomenon (observable event) is called **reinforcement.** If one wave arrives half a wavelength late, the high pressure region of one wave will be cancelled by the low pressure region of the other. The result is no sound. This is called **cancellation**. Where reinforcement occurs the waves are said to be in phase with each other. Elsewhere the waves are out of phase and partial or complete cancellation occurs.

DISTORTION

Distortion is any unwanted change in the waveform (shape of a wave). When waves that are odd fractions of a wavelength out of phase meet, the actual shape of the sound wave is altered. This results in one kind of distortion. (Distortion may also be caused electronic equipment but here we are just considering sound itself.)

APSORPTION, REFLECTION & REFRACTION

When sound meets with a large surface the sound may be **absorbed** or **reflected** depending on the nature of the surface. Hard, glossy surfaces such as glass, bricks and ceramic tiles are efficient reflectors; porous surfaces such as carpets and curtains are good absorbers. **Refraction** is the change of direction of a wave as it passes from a medium of one density to a medium of another density. Different temperatures can cause layers of air to have different densities. If the upper layer of air is warmer (less dense) sound will be bent or refracted downwards. This often happens out of doors at sunset. The result is that sounds travel farther. When the upper layer of air is cooler (and therefore denser) sound waves are refracted upwards. This is why sounds do not travel so far on a hot summer's day.

RESONANCE

A sound engineer is also concerned with resonance. All objects that can be made to vibrate have a certain frequency at which they will vibrate most strongly (ie. with maximum amplitude). If a body is excited with a whole range of frequencies it will vibrate approximately equally in response to them all *except* those frequencies nearest to its own natural frequency. At one frequency it will vibrate most strongly. This frequency is called the **resonant frequency** and the condition is called **resonance**. A string of a musical instrument will vibrate at one frequency, its resonant frequency, whether the string is plucked, bowed or struck. Air particles have mass so any enclosed body of air (eg. the pipe or "tube" of a clarinet) has a resonant frequency. The air contained in a hall or studio can have resonance too, resulting in certain sounds being unduly emphasized.

FREQUENTLY ASKED QUESTIONS: SOUNDPROOFING AND ACOUSTIC TREATMENT

Q What's the difference between soundproofing and acoustic treatment?

Acoustic treatment, in the context of a recording studio, generally deals with the acoustic quality of the room from a listener's point of view. In other words, if you monitor in a control room that has been designed using the correct acoustic treatment, what you hear is likely to be more accurate than the same recording played back over the same speakers in an untreated room. Soundproofing, on the other hand, is specifically designed to increase the degree of acoustic isolation between the studio and the world outside -- cutting down on noise that leaks into or out of the studio. Sound isolation works the same both ways, so there's no difference in approach to keeping sound in or out.

Q I've heard that sticking egg boxes or acoustic foam to walls will help soundproof a room. Is this true?

Egg boxes may make a very tiny improvement to some aspects of a room's acoustics by breaking up reflections from hard surfaces, but they are useless in terms of soundproofing. The same is true of lightweight suspended ceilings, acoustic foam and even Rockwool Rockwool tends to be used for acoustic treatment or for damping out resonances inside partition walls. All these materials have their uses, but they're mainly for acoustic treatment, not for soundproofing.

Q So, what are the requirements for soundproofing?

The term 'soundproofing' is rather misleading, because in most real-world situations, you can cut down on leakage but you can't get rid of it altogether. Sound isolation is a more accurate term. The simplest way to attenuate sound is to put a solid wall in its way -- the more solid, the better the isolation you'll get. As a rule, if you double the mass of a wall, you halve the amount of sound transmitted through it. Unfortunately, sound isolation tends to fall with frequency, so even though you may be able to get the mids and highs under control, the chances are that you'll still be able to hear the bass drum and bass guitar thumping away from outside. That's why when you walk past a club, all you can hear from outside is bass.

To give you some examples of what to expect, a single brick wall might have a quoted Sound Reduction Index (SRI) of 45dB (this is averaged over a range of frequencies, so the bass-end isolation will be rather worse than this figure) while a domestic panel door might only give you around 10dB of isolation. Because the degree of sound isolation depends largely on mass, lightweight solutions such as partition walls work noticeably less well than solid brick or concrete. However, there's another useful fact we can utilise -- two walls are always better than one. If a single wall can reduce the sound leakage by 45 or 50dB, you might imagine that two separate walls spaced apart might give you 45dB for each wall, or 90dB altogether. Sadly, unless the walls are separated by a large distance, the air between them couples energy from one wall to the other and reduces this figure considerably. However, and this is the important bit, two walls with an air gap in between will always give better results than a single wall of double the thickness. The wider the gap, the better the sound isolation, especially at low frequencies.

Q But commercial studios often include plasterboard-covered studding walls. Surely these can't have enough mass to work properly?

In most serious studios, any partition walls have at least three layers of plasterboard on each side. This builds up enough mass to provide adequate isolation, though at the very low end, brick or concrete is still better.

Q OK, so I can build high-mass walls, but I can't make the windows out of concrete. Won't a lot of sound leak in and out there?

That's true, and even using the 'two layers are better than one' theory, double-glazed windows offer only a limited amount of sound isolation compared to a high-mass wall. Nevertheless, double-glazing is a lot better than single-glazing. The wider the gap, and the heavier the glass, the better the isolation. Adding secondary double- glazing inside an existing double-glazed window works even better, but all your glazing must be airtight, otherwise the sound will just leak around the edges. Of course if you don't need the light, you can board up the window and fill the space with sandbags!

Q But I can't board up the doors, otherwise I won't be able to get into my studio!

Doors can be a real problem, because no matter how thick and heavy you make them, they'll always leak a lot of sound compared to the surrounding walls. You also have to work harder to keep them airtight and you'll needs seals all the way round, including the bottom. The best solution is to use two doors separated by at least the thickness of your wall. A pair of heavy fire doors (these are usually filled with plasterboard) can work well, but make sure your doorframe can take the weight.

Q I think I can deal with the walls, doors and windows, but what about the floors and ceilings?

Concrete floors don't usually cause problems because of their high mass, but wooden floors are a different story, especially if you have neighbours trying to get to sleep in the room below. Being realistic, there's nothing simple you can do to a wooden floor to increase the isolation to the extent that you could play drums without upsetting the people below. Even the expression pedal from a piano will come through a wooden floor loud and clear! However, you may be able to make an improvement if you're using the room to mix or to play less noisy instruments. Fitting heavy felt carpet underlay is a good start, and if you're into DIY, you may even be able to make a floating floor (a kind of false wooden floor that rests on a resiliant base of Rockwool or neoprene).

It also helps to get noisy amps and speakers off the floor. You can stand instrument amps on blocks of foam rubber, though these days there are so many good DI solutions that you might be better off going for one of those. Thick neoprene slabs between your monitors and their stands can also help.

Q That's a lot to think about, but where should I start?

Look for the weak areas first. There's no point worrying about your walls if the doors and windows offer poor isolation. At the most basic level, you need as much structural mass as possible, air-tight seals around doors and windows, and double doors if you're going to make much of an improvement. Double-skin walls are a good idea, but there's little point worrying about the fact that you only have a single-thickness wall if the real problem lies elsewhere.

Also, consider structure-borne sound. Sound energy travels very efficiently, as mechanical vibrations, through wooden joists or steel girders. If you inject sonic vibrations into these components, they'll bypass all your careful soundproofing. Pay particular attention to floor supports as most unwanted energy gets injected into the floor.

Q If soundproof means airtight, how do I breathe?

For fresh air, you'll have to open the doors between takes unless you can afford a proper studio ventilation system. However, a simple air conditioner that cools and recirculates the air will make the room a lot more comfortable to work in providing you do remember to open the doors from time to time.

Q Assuming the noise levels are workable, what can I do to set up a reasonably accurate monitoring environment -- short of employing a studio consultant and spending a lot of money?

If you're doing any commercial work, then paying a consultant might not be a bad idea as it can save you from wasting a lot of money doing the wrong thing. Even so, there are simple things you can do to a domestic room to make it work better as a mixing environment.

For monitoring, it's important to have a room that's not too live -- everything should be as acoustically symmetrical as possible. Ideally, the reverb time should be even across the audio spectrum, though even in the best studios, it tends to rise a little at the bass end. In a domestic room, excessive reverb can be addressed reasonably well by carpeting the floor and using a few soft furnishings, though it also helps to fix a square metre or so of acoustic tiles to the walls each side of the listening position to kill flutter echoes. A soft sofa at the back of the room can also help, along with shelves, to break up reflections from the rear wall.

Strong early reflections from the monitors should also be avoided so, if at all possible, put your monitors on stands behind the mixer, not on the meter bridge. You probably won't need to worry too much about the bass end providing you use nearfield monitors that don't go too low. If you're getting reflections from the ceiling above the mixer, consider putting another foam absorber or two up there as well.

Q How much does the room that I'm working in affect which type of monitor I should choose?

While it is important to master commercial mixes over full-range speakers, a two-way nearfield monitor that rolls off gently below 50 or 60Hz is probably best for use in the typical project studio. Pumping too much bass into the room will just confuse the sound and may lead to an inaccurate mix. Studio monitors should be accurate and revealing rather than flattering, and they should sound smooth enough not to fatigue your ears when listening for long periods. Active monitors often perform better than passive models and they relieve you of the task of picking a suitable power amplifier.

Whichever speakers you have, it's a good idea to listen to some known pre-recorded material over the system before mixing. This gets you used to what your mix should sound like in your mixing environment. Not all CDs are well recorded, but if you can find something half decent in approximately the same style as the music you're working on, it will help you keep a sense of perspective.

Q Where should I put the monitors?

Putting speakers too close to corners tends to emphasise the bass in an unpredictable way, so try to site your speakers away from the room boundaries and make sure the setup is symmetrical, with the tweeters pointing at your head in your normal monitoring position. Relatively small changes in speaker position can affect the sound quite significantly, so experiment with moving your speakers forward or backwards while some known commercial material is playing and aim for a smooth response, especially at the low end. If some bass notes seem louder than others (from your normal monitoring position), move the speakers around until the problem is minimised. Mounting the speakers on solid stands makes quite a difference, and hi-fi stands that you can fill with dry sand also work well.

Q Where can I obtain the materials I need for soundproofing and acoustic treatment?

Most of the materials can be found at regular builders' merchants or DIY shops, though studio-quality door seals, neoprene and acoustic foam are best obtained from a specialist studio supplier.. Foam acoustic tiles are offered for sale by most studio suppliers, though you can also use fire-retardant furniture foam of around 100mm thickness for mid-range and high-frequency absorption.

Q. Are you absolutely sure egg boxes wont help?

YES!!!!!!!!!!!!!!!!!!!

A few websites you may find useful

Sound On Sound is Europe's leading recording magazine. The website features a huge resource of searchable articles from over a decade of publication. Highly recommended.

http://www.soundonsound.com/articles

Modern Recording Techniques by Huber & Runstein is a regularly revised book generally considered to be the studio Bible. The website is excellent, though I'd recommend getting a hardcopy as well. Currently at it's 6th edition, older secondhand copies can be had pretty cheap on ebay, and while they may not have the lowdown on the latest gear, the important stuff that everyone should know never really changes.

http://www.modrec.com/

General recording websites

http://homerecording.com/

http://recording.org/

http://www.pcmus.com/AudioTips.htm

Acoustics

http://www.ethanwiner.com/acoustics.html

Discussion forums

http://forums.musicplayer.com/

http://recording.org/modules.php?name=Forums

Jargon buster

http://www.guitar9.com/glossary.html