MAHO-NO-KATANA
Sound Physics – Main Lesson

Tetsu the Samurai tapped his magic sword, his *Maho-no-Katana*, on a stone, it rang like a giant tuning fork, the 256 cycles-per-second tone of middle C in fact. He pondered on the nature of sound as he watched his two friends try any number of aural methods to attract the attention of the sleeping ferryman on the other side of the lake – but they failed.

"Wait till tonight;" said Tetsu "till then, find me a length of bamboo and hollow it out." At the designated time, when the surface of the lake was mirror-smooth, there being only a slight offshore breeze, Tetsu placed the bamboo 'megaphone' to his tips and called out. The distant ferryman was jolted from his slumber and fell to his oars!

This is a morsel of a story I told to a Class 1 in Japan recently in their *Physics Games* main lesson. Embodied in the imagery were many core principles of sound science. Later the children called to each other through their own improvised megaphones, manifesting the 'games' element in this introduction to the physical sciences in general, and sound physics in particular. As such, this is primarily a *will* lesson.

The *feeling* element however has primacy in the *Sound Studies* main lesson in Class 4. Here worldly phenomena and anecdote is added to the story. (Details of these two main lessons can be found in my books *World Without – Child Within* Class 1, and *Child Awake* Class 4.)

From will to feeling to *thinking* in sound education, and we arrive at the *Sound Physics* main lesson in Class 9. Here we interpret many of the elements earlier learned into theorems and equations. In Class 1 we *Do* sound, in Class 4 we learn to *love* it (through enjoyment) – and in Class 9 we *understand* it. Again the Steiner curriculum is an exemplary model of wisdom and vision.

In the 12-year Educational Zodiac, beginning with Cancer (quality of Initiative according to Steiner) and moving clockwise, Class 9 is the Pisces year, with its Sense of Hearing. What better time to raise this remarkable faculty, the first of the four 'spirit' senses, to higher consciousness? How, in Steiner schools for decades, have the 15-year-olds marveled at the beauty of the forms created by the Chladni Plate.

This is merely a heavy foot-spare place of steel mounted horizontally on a single support. Dry sand is sprinkled on it, and a violin bow drawn across the edge. The – unique every time! – geometric patterns of nodes and anti-nodes appear – *moho-no-tetsu* indeed (tetsu being Japanese for steel) so orderly yet so beautiful, seem quite miraculous – sound science at its best!

Pisces surfaces again, so to speak, as being one half of the ruling dichotomy for our own 'civilization', the *Anglo-Nippon*. Since 1413, Pisces and Virgo rise in the vernal equinox of the northern and southern hemispheres respectively.

In Australia we are evolving under the *conscious* moral imperatives of a Virgo Age, while our destiny development (the 'quality' of Pisces) is more a subliminal one – this parallelism is one of thinking and will respectively (the Quality of Virgo is soberness). A physical expression of the northern hemisphere Piscean 'sense of hearing' age is found in music.

It was around 1413 when humanity created formal music notation. This allows people to play music from the Medieval Age much as it might have sounded at the time. No music, the melodic element at least, prior to this date is known. In the 12-fold *Subject Zodiac* Music, not surprisingly, lives in the house of Pisces.

In fact 'ears' is a good place to introduce this Sound Physics 3-week unit; though the anatomical study should not be too detailed, due to this being a physics rather than biology lesson. However the mechanics of hearing should be explained, and hopefully artistically drawn. After all, without ears, sound would be an abstraction rather than a reality – yes?

No! – it should be explained that every physical object, even fire, is an 'ear'. Steiner speech exponents can influence a candle flame with sound – not breath. This is because the flame – and everything else – *resonates*, which is how sound is perceived.

Imagine two identical doors, but made of different timbers; a knock on both sounds completely different, as the timbers resonate to their own individual frequencies. These two door-ears hear the same sound, the knock, but 'speak' (create their own sound) differently. So it is with people; which helps explain why certain sound or music can be loved by one person, hated by another. The eardrums of old people resonate differently from those of children or teenagers – especially teenagers!

Rudolf Steiner continuously reminds us that in science teaching, we must relate the phenomena to Man. In this case, the human is not just a hearing being, but a *sounding* one as well. As such, the students should have the larynx explained, and subsequently drawn. After all, the human voice is the most versatile sound-creating instrument on earth.

Animals can call louder and longer than humans, but not wider. The *range* of sounds of the human voice, from those emitted by opera singers to the vast array of sounds in the vast array of languages, astounds observers of those tiny, beguilingly simple organs, the vocal chords. The human ear is also the most widely perceptive sound receiver on earth. Again animals win on the specifics, with bats and whales being extraordinarily sensitive to UHF and ELF frequencies respectively.

At this point it might be of value to differentiate between the three aural 'qualities'. These are music (or speech), sound and noise. Music is exclusively of the human being; sound is the (usually sonorous voice of nature, like a babbling brook or bird 'song'; and noise is mostly mechanical in origin – in most cases dissonant to the sensitive ear. The word sound relates to well-being or health, as in 'a sound mind'; while noise is derived from 'nausea' – sickness!

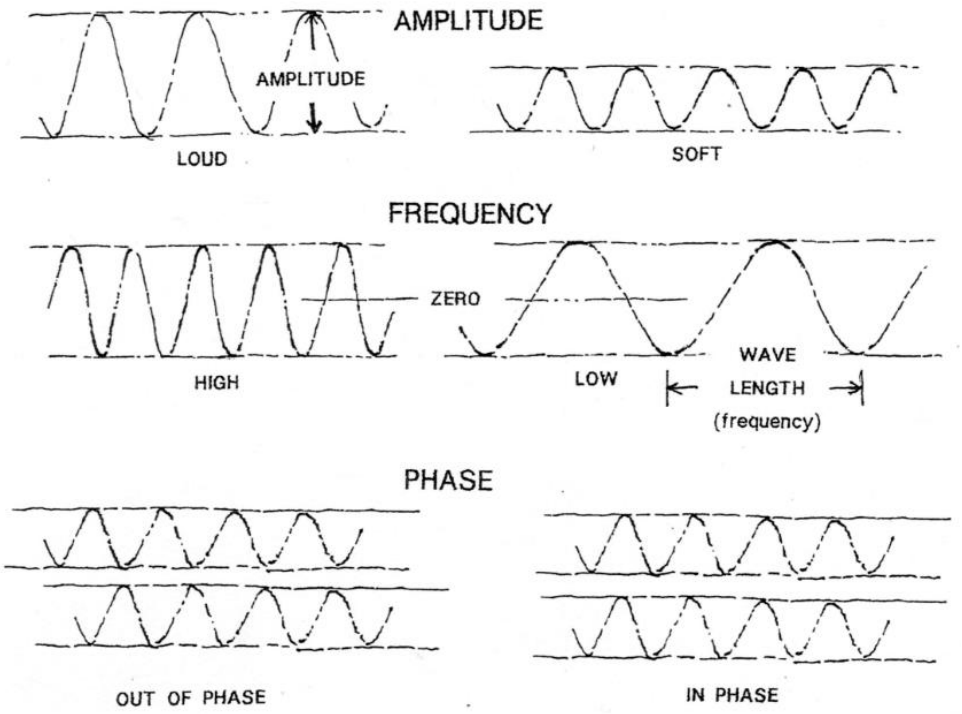
This message was sheeted home to my class when, in relation to this unit, we had a visit from a spokesman from the State Pollution Control Commission. He alerted the students to the dangers of an increasingly clamorous world. He also described the Commission's role in research on both the effects and limits on noise in both suburban and industrial areas .He demonstrated the use of the sensitive instruments used to measure noise; as well he showed us a short film.

Sound Physics is the second in a 5-year Physics program, beginning with Electrical Physics in Class 8 (see my book *La Pleroma*) – and continuing on to Light Physics in 10 (later in *this* book); thence to Heat in Class 11 and Atomic Physics in 12. The science main lessons are divided into three strands, Physics-Body, Chemistry-soul and Biology-spirit (or will, feeling, thinking). The last of course embraces the Study of Man. Science is, of the four main lesson streams, that of the Physical Body – that which can be touched. The other three are Language-Ego, Maths-Astral and Social Science-Etheric.

This 'touch' element illuminates another spiritual reality: science, in the 12-fold *Educational Zodiac*, lives in the House of Cancer. The Crab, according to Steiner, expresses both the sense of touch and the Philosophical Viewpoint of *Materialism.* "Touch me not." Said Jesus to this 'Cancer' disciple, Thomas. He it was whom the Lord sent to India – against The Doubter's (materialism remember) protestations. Cancer was the vernal sign in the great Indian Age.

In the spirit of the manifest world being both an ear and a larynx, I called my Sound Physics unit *the World Speaks – The World Hears*. All things give out sound of some kind when struck be an 'exciter', whether something physical or even another sound. A violin string will resonate, hence sound, in sympathy with another of the same frequency.

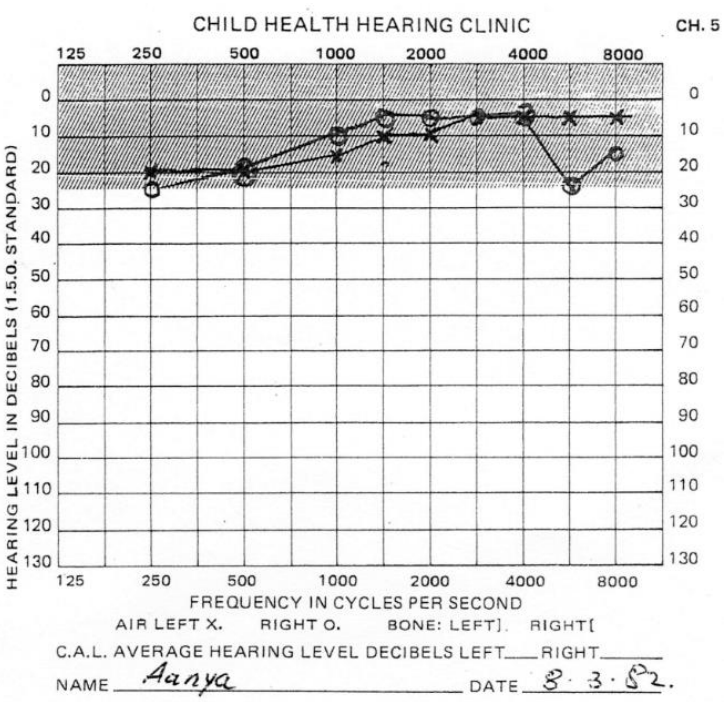
This sound synchronicity is called 'being in phase' – out of phase is when the frequencies of the same cps have a different starting point. When I rode motorbikes in my wayward youth, two identical engines would mysteriously enter an in-plane state, and the pair of us would literally *hum* along the highway – side-by-side!



With animals the ear shape reveals what kind of sound they hear, or at least are sensitive to. The larger the ear, in relation to the body, the more acute the hearing. The human auricle indicates our own, highly varied, hearing-listening abilities. Turned up ears, like Rudolf Steiner's, listen to the voice to the Spirit, their opposite to that of the earth. This is only one example of ear physiognomy; a study which is fascinating, though not really appropriate for this lesson.

An early English explorer watched in amazement as, with sound pulsation alone, Tibetans raised a large stone 400 feet from the plain to a cliff top. Even today, experts conclude that many of the large stones perched on Tibetan cliffs, geologically originating from the lowland, simply couldn't be raised on high by any known means. I don't know if numbers were important but the report was quite specific: In a parabolic curve surrounding the great stone (which rested over a depression), 200 priests chanted to the accompaniment of 13 drums – one huge – and six of those very long Tibetan trumpets. The stone took only four minutes, at a speedy 100 feet per minute, to reach the top!

Vital information is ear health; as babies can hear up to 40,000 cps, they are highly sensitive, hence highly vulnerable. My heart ached one day at an airshow to see a tiny tot clutch its ears in agony as the jets screamed overhead – the goggling dad was blissfully ignorant of his son's anguish, and possible long-term auditory damage! Normal adults of course can only hear half this frequency range – the aged a lot less than 20,000 cps even.



The students each had a hearing test in this lesson – practical and informative.

When studying the 16 elements of voice production, their role in resonation, individualization and excitation should be described. The 16 are: lips, mandibles; teeth; alveolar ridge; hard palate; soft palate; tongue; nasal cavity; mouth cavity; pharynx; epiglottis; trachea; lungs; larynx; uvula; Eustachian tube. 16 is the *Number of Life*; we are most aesthetically alive when expressing - in the living breath – speech or song. Even though Steiner calls the ear, and its sense of hearing, a declining organ, it is still among the greatest of living miracles.

Although our ears don't move like most auricled animals, they still serve us faithfully throughout our lifetime. The incredible thin eardrum is a mere centimeter round, and is angled to avoid damage; while the all-important oval window is only the size of a pinhead!

The ear bones gear down the sound, and are fully developed by the 7th year – the only bones in the body that are. In fact these are the same size in the new-born as they are in an adult; again unique in the human osseous world. Further protection is afforded by two muscles, one on the tympanum, the other on the stapes; these tauten to protect the ear against loud noise. This is a complex yet curious evolutionary factor, as there were very few really loud noises in a pre-industrial age.

The cochlea is made of bone to resist pressure changes in the contained liquid – because a fluid cannot be compressed. The round window is, er, round, and deals with the *physical body* of the sound; the circle being, of the four classic curves, that of the physical body. The oval window perceived the *life body* of the sound – the ellipse is the etheric curve.

Many musical instruments are based on the ear and larynx. A violin has the taut strings of the vocal chords, the sounds of which are received by the ear-shaped body of the instrument. The neck even has the cochineal spiral! Of all instruments, the pipe organ is probably the most voice-like; there we have the bellows-lungs, pipes-pharynx, keyboard-larynx and tongue-stops!

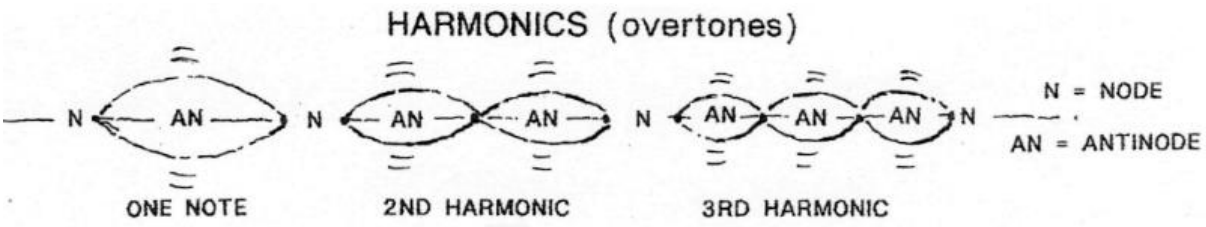
At some time one must cross the thorny threshold into the hall of hard science, the *physics* of sound itself. The following is not intended to be a comprehensive content plan, merely a guideline; the diligent teacher will have piles of Sound Physics books on both his/her preparation desk and in the classroom. These will be on both the basic facts as well as the more esoteric aspects of the subject.

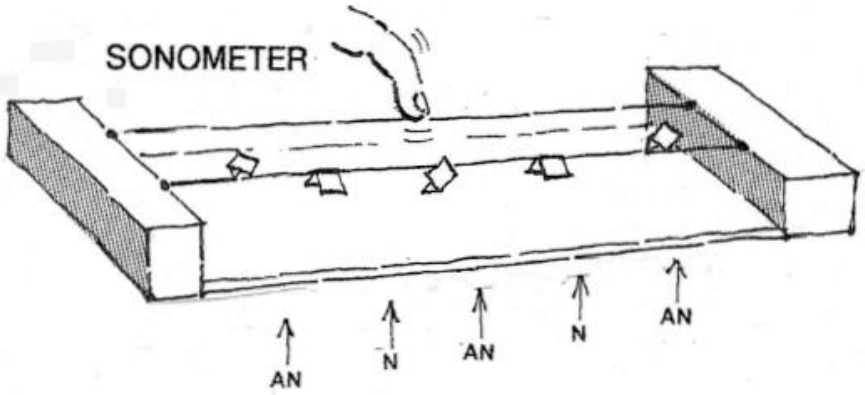
Frequency is measured in cycles per second, cps; the *pitch* of a sound, its amplitude, with its loud-soft factor is measured in decibels (d) – 1 *phon* unit is 1 decibel.(1 Hertz, Hz, is 1 cps; a cps is also called a 'period'.) The average person can hear up to 130d.

Resonance, in soul matters as well as sound, is when frequency of applied force equals frequency of object. It's curious how middle C, tuned perfectly to the mid-range of the human ear, is 256 cps – why? Because this is the number of the Earth, 4 to the power of 4 or 16 squared! 256 is one of the most cryptic numbers in occult numerology. Higher frequencies tend heavenwards – lower into the Abyss!

The mid-range frequencies – and middle C in particular – resonate with the innate frequencies of our own ear apparatus. As such, these sound louder than notes above or below, even through they're not. This is a good test of amplitude sensitivity for the students. The saxophone was specially *invented* (with the exception of the piano, all the formal orchestral instruments – which the sax is not – were *inspired*) to synchronize with human hearing by being pitched as closely to the human *voice* as possible. The saxophone sounds louder than equivalent instruments, especially in smoky jazz clubs, the first venues to embrace this most *human* (if not musical) of instruments.

The highest frequency known is 10 to the power of 29 cps – even dogs can't hear this one – the Choirs of Angels perhaps? Frequencies even change their effect environmentally; mice subject to loud sounds at night died – but were unaffected by the same sounds during the day. Apply this to your own experience; I find a barking dog an irritation in the day, but a torment from hell at 3am. Harmonics, especially as they include interesting number properties, are an essential study topic. A tuning fork is one note, with no harmonics. This is drawn as a ellipse – the first harmonic is a lemniscate; these are the etheric and astral curves respectively. A two-wire sonometer demonstrates harmonics well; the second wire dances in sympathy when the first is plucked. Little folded pieces of paper jump off at the antinodes, but stay on at the nodes.





As we all know, sound decreases with distance, due to the amount of air molecules to be moved. The evening air was *thinner* when Tetsu hollered his hallow. Conversely no sound travels through a vacuum, such as space. A sun could explode quite nearby, and you wouldn't hear a thing – or feel a thing probably!

Acoustics is an interesting area of study, more of which can be found in my book *Many Mansions*. This deals with the spiritual implications and historical evolution of sound in architecture. More pragmatic areas in does not cover, alas: like sound insulating in relation to the nature of materials (compacted molecules again); wall thickness; sealing of ceilings (and other cladded surfaces). A mere gap of a centimeter or two can cancel out a huge percentage of benefits of sealing for sound attenuation. Walls between classrooms should be scrutinized for even tiny gaps. Then there are echoes, including single and multiple reverberations.

The bet musical reverbs are in the range of 1 to 2 ½ seconds. The opposite of the echoic, are the *anechoic* factors. These and other sound phenomena were observed by my heroine Sabina in the *Many Mansions* acoustics article. I named her after Wallace Sabine, founder of modern architectural acoustics. Of course the spiritually-inspired, more instinctive Sound Masters of the past put Wallace's modest achievements in his Harvard University Lecture Hall design in the shade.

Sabine found that the three main factors in sound transference were reverberation, interference and resonance. For fine sound performance, all three need to be in harmony: *Reverberation* is the amount of sound which bounces around the room before it becomes audible; both materials and room volume affect this. A sound can be made 'dead' or 'alive' by manipulating *Frequencies*. *Interference* is when source sound waves meet reflected waves. These can either amplify or cancel out a sound – in extreme making it inaudible.

Acoustic architects now plan the sound proportions of a room to suit the function. For example; the ideal reverberation time for piano and chamber music is one second – for orchestral one to two seconds – and for choral music two to five seconds. Too bad if all three, and more – like heavy metal bands! – share the same performing venue. With many rock bands' inhuman amplification, they don't give a toss about reverberation – except that created by their reverb pedal of course!

Another more arcane area of sound exploration is fog guns; the particular frequency of these, usually near seacoasts, can dispel pea soup fogs and other hazardous weather phenomena. And while on the mysterious (the students love this bit!), how about Joshua bringing down the walls of Jericho with his ram's horns – or the eerie moaning of auroras – or the 'Singing Sphinx'?! this last was crated by air in a hollowed chamber heating up and expanding, to escape under pressure through a small hole in the mouth – the mid-day desert wails were enough to make a Taureg's beard stand on end!

Lucknor, the "Ear of the Earth' in another desert, the Gobi, has a more plaintive desert song' this time creating music with distinctive wind and topographical features. The Chinese unconscionably use this region to test nuclear bombs. For Mother Earth, this is like having a firecracker dropped into our own sensitive ear!

All this points to the earth, as well as its teeming habitués, having a voice. Many of these earth songs have very long wavelengths, or infrasound, ELFs (extra long frequency). The inverse of this is ultrasound, UHF (ultra-high frequency). Most of the frequencies of the human body are in the ELF range of 0 to 100 Hz. ELFs penetrating from without are very difficult to shield. The Germans knew this when they developed their WWII 'whirlwind cannon'. This sinister device could not only scramble the enemy's internal organs, but, as in Jericho, knock down walls with sound.

Some other earth voices are storms, volcanos, earthquakes and waves. Many people are affected by these Voices of Gaia, suffering maladies such as nausea, loss of balance (middle ear problems), disorientation, hysteria, blurred vision and lassitude.

Sound vibrations are really created, like breathing, by alternating high- and low-pressure waves. A bell rings, sending out a wave of *compression* (high pressure, of about 1.1kg/sm2 at sea level); this is followed by a resile of low pressure, a *refraction* as it's known – then, at regular intervals; compression, refraction, compression…and so on.

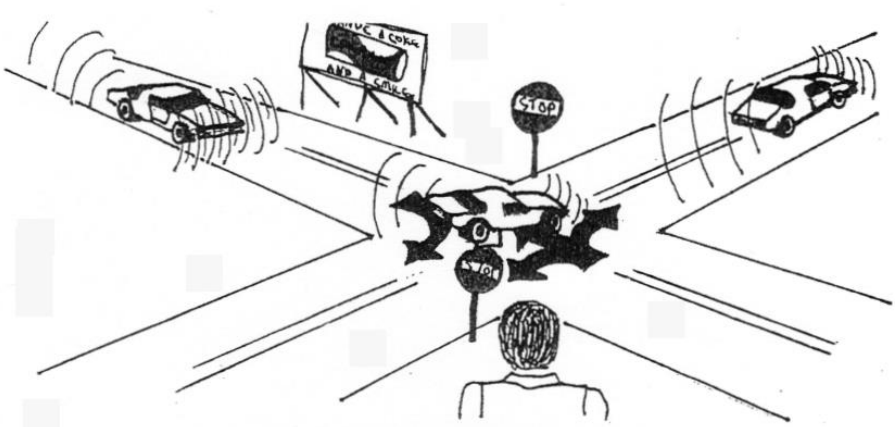
The Great Caruso's celebrated smashing of champagne glasses (with his voice!) occurred when his frequency matched exactly the innate frequency of the glass. This is the same vibration we manifest when rubbing a wet finger round the top of the glass (a good in-class sound exercise). While on singing, the *Diatonic Scale* has a curious mathematical progression; from middle C doh 1, to the next octave doh 2, Ray is 9/8; me 5/4; fah 4/3; sho 3/2; lah 5/3; te 15/8.

The wavelength of a sound is dependent on its speed and frequency. The speed varies with the conductor it travels through. At 0° in air, the speed is 534.2 kilometers per second; for each 1°c above, the speed increases by 9.6 k/s – or approximately a meter faster for every 1 degree above zero. The equation for this is wavelength = speed/frequency: Example – the wavelength of a sound, if the speed is 534 and the frequency 2000, is W = 534/2000 = .0267. Conversely speed = F x W, and frequency = S/W.

The mystery is that these sound waves travel through the air without moving the wind. This is a bit like the – etheric – waves passing through water and not moving the bobbing cork. This ether sound is that received by the *elliptical* oval window of the ear. The (round window) physical nature of sound expresses through the fact that it creates an invisible *spherical* form, traveling outwards in all directions as it does. Environmental factors influence this of course; Tetsu could more easily be heard with his voice carried by the slight breeze in the direction of the ferryman.

Then there are obstructions; low frequency sounds overcome these more easily than high – which accounts for the former, like trains and fog horns, being more common ambient sounds in built-up areas.

Of course echo-location an sonar should be mentioned in this section – and that old favorite, the *Doppler Effect*. One can just take the students out to the road with a stop watch to demonstrate this one; then record the principle later in their main lesson books.



Class 9 Doppler Effect drawing;
big on science, road rules lesson comes later!

We earlier looked at the difference in the speed of sound as it travels through different air densities, one variant being temperature. Speed is dependent on whatever material the sound travels through, from steel to water. To find the velocity of sound, you need to know the elasticity and density of the material traveled through – Velocity = Elasticity/Density. Starting with a vacuum at 0 meters per second; we have water at 1,463 m/s; metal at 5200 m/s (approx.) and rock at from about 4000 to 6000 meters per second.

Because of the different speeds of sound at different levels of the atmosphere, determined both by air density and temperature, the sound can be refracted (bent). The call of a high-flying bird might be heard more easily hundreds of meters away than directly underneath. The latter is known as a 'zone of silence'; a state hard to create in a class of 15-year-olds! In extreme cases, like a high-altitude explosion, sound can travel 80 kilometers or more without anyone hearing it in between!

The 'sound barrier' raises some interesting questions; it is not the explosion of the gunshot, but the bullet breaking the sound barrier which creates the *Bang!!* A bullet fired into the ground is almost silent. A supersonic aircraft, or a whip crack (at 1223 kilometers an hour, the nominal speed of sound) breaks through a layer of sound compressed waves. The sudden rise and fall of pressure creates the 'sonic boom' (tautology, but never mind!).

A new measurement scale, the *mach*, was created to record this. An American balloonist free-fell from 40,000 meters to become the only person to break the sound barrier with is own body – the bang of a lifetime I bet!

Ultra-sonics have found an increasing number of uses, from watching baby in the womb (defiling the mystery I say), to 'cavitation', where ultrasound passes through a liquid creating a range of reactions, hence uses; like mixing the 'unmixable' mercury and water. Sound is also used for homogenizing, emulsifying, cleaning, electroplating – and drilling holes in brittle substances like glass.

A description of Thomas Edison's first recorded sound gives the human face to Sound Physics. His 1877 scratchy old "Mary had a little lamb" is a far cry I quality from the sophisticated sound technology engulfing us today. This supersonic progress is enough to make Mary retire from sheep-care and get into something more up-to-date – the first woman samurai perhaps?