PHYSICS OF SOUND INFO SHEET

SOUND WAVES: Sound waves are generated by a sound source. Once the source is activated, the energy created by it repeats over and over again – in the form of waves – as it moves through a medium (such as air or water). (Think of dropping a pebble in a lake). As the energy moves through the medium, it vibrates the particles in the medium (think about how you can feel the booming low bass of a song in your body). In singing, sound waves are created by the vocal cord vibrations and travel through the air (as well as anything else in the room).

FREQUENCY: The frequency of a pitch/sound refers to how often the particles of the medium vibrate when a wave passes through the medium. Put another way, the frequency is how quickly the sound wave repeats itself over and over again in the medium. (Put your fingers on your nose and humm a high note, and you'll feel the vibrations moving faster through your nose than if you hummed a low note).

Measurements: Frequency is measured in cycles per unit of time called Hertz (Hz). 1 Hz is equal to 1 cycles (repetition of the wave) per second). Middle C has a frquency of about 262 Hz. This means that each second, to make a Middle C, your cords are vibrating 262 per second, and each one of those vibrations is creating a wave of energy that is then sent out into the world at that speed. In general, men's vocal folds can vibrate from 90 - 500 Hz, and they average about 115 Hz in conversation. Women's vocal folds can vibrate from 150 -1000 Hz, and they average about 200 Hz in conversation. Here is a handy list of pitch frequencies: http://www.phy.mtu.edu/~suits/notefreqs.html

INTENSITY: Besides frequency, intensity is the other important aspect of a sound wave. Intensity is how much energy is being carried in the sound wave. The greater the amplitude (the largeness) of vibrations of the particles of the medium, the greater the rate at which energy is transported through it, and the more intense that the sound wave is. In other words, if the particles vibrate a lot when the sound wave hits them, then the intensity is high; if they only vibrate a little, then the intensity is low.

So, really, intensity (in sound) can be roughly defined as volume. The higher the intensity, the louder the note is. (This is mostly true. Because of the human ear's tendency to amplify higher range frequencies (1000 Hz to 5000 Hz), high notes will seem louder to the human ear than low notes, even if sung at the same intensity. Also, it should be noted that the intensity gets less the farther the sound wave travels – for example, you sound quieter to someone far away.)

Measurements: While officially we measure intensity in Watts/meter (how much energy is contained in the sound wave per every meter it travels), decibels (dB) is the most common way to rate volume/intensity. (The threshold of hearing is assigned a sound level of 0 dB; this sound corresponds to an intensity of $1*10^{-12}$ W/m2.) Rustling leaves are about 10 db; very loud music in headphones is 100 db, and your eardrum will pop at 160 dB.

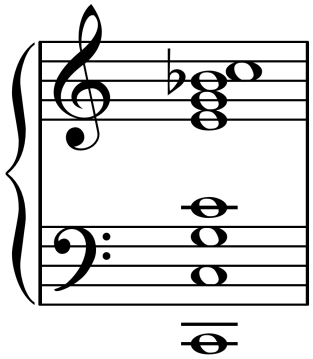
<u>THE DIFFERENCE BETWEEN FREQUENCY AND INTENSITY:</u> Frequency is how often the sound wave repeats; intensity is how much energy is contained within the sound wave. So if I sing Middle C softly, that sound has a low INTENSITY, but the same FREQUENCY as if I sang a Middle C loudly. Conversely, I could sing a Middle C or a Middle G at 30 dB – their INTENSITY would be the same, though their frequency would be different.

<u>HARMONICS:</u> When the sound waves interacts with a medium/object, the medium/object has its own tendencies, and so will tend to vibrate at a particular frequency or a set of frequencies. The frequency or frequencies at which an object tends to vibrate with when hit, struck, plucked, strummed or somehow disturbed is known as the *natural frequency* of the object. Harmonics are created by the interaction of fundamental sound wave (pitch) with the *natural frequencies* of the object it is moving through. When you sing, we hear the harmonics that are created through the interaction of the *sound wave frequency* and the *natural frequencies* of your resonance chambers.

A silly example is that if you say a sentence (a sound wave frequency) to a nice person (object's natural frequency), they will hear it as a kind statement (resulting harmonics); but if you say the same sentence (a sound wave frequency) to a mean person (a different object's natural frequency), they will hear it as an insulting statement (different resulting harmonies).

<u>Measurements:</u> Our language on describing this is a little convoulted. The pitch (frequency) of a note is sometimes called the fundamental. The 1st Harmonic of a sound is the fundamental (pitch). The rest of the harmonics go up from there. The 2nd harmonic is usually an octave up, and 3rd Harmonics is a musical fifth above that. Sometimes the word overtone is used. The 1st Overtone is the same as the 2nd Harmonic – don't get confused!

Visual of first 8 harmonics:



link to example of what the first 16 overtones/harmonics sound like
https://en.wikipedia.org/wiki/Overtone

<u>TIMBRE</u>: In music, timbre (*tam-bər*) is also known as tone color or tone quality. Different types of sound production, such as different people's voices or different instruments sound different even when singing/playing the same note. This is timbre. Timbre is the result of harmonics and intensity/volume (sometimes talked about together the *spectral envelope.)*

You could stop there and have a great undertanding of the physics of singing, but if you want to see how your physiology relates to the physics, then, keep reading…

RESONANCE: In singing, resonance refers to the sound wave moving through the spaces in your throat, face, and head as it moves through your body and out into space. As singers, we modify the size and shape of those resonators to get the best sound possible.

In physics, resonance is defined as the phenomenon that occurs when a vibrating system (or external force) drives another system to oscillate with greater amplitude at a specific, preferential frequency.

So, let's combine those definitions for a clean statement on what happens in the physics of singing. The vibrating system (the sound wave created by the vocal cords) is directed through the other system (the resonance chambers) to make that system oscillate (vibrate) at specific preferential frequencies (the harmonics that create your best sound).

FORMANTS:

As we know from the Harmonics section, when sound waves interact with a medium/object, the medium/object has its own tendencies, and so will tend to vibrate at a particular frequency or a set of frequencies – this creates the *harmonics*. Within those harmonics created, interestingly, the *sound wave frequencies* that most 'jive" with those *natural frequencies* of the object will increase in amplitude. In other words, since the sound wave and the object share a certain frequency, the amount of vibration at that frequency will be amplified…and so it will be louder.

So, as the sound wave goes through all the particular objects of your resonance chambers (throat and face), each part of your resonance chambers will highlight a certain frequency or set of frequencies. The frequencies that are highlighted by your resonance chambers interacting with sound waves are called *formants*. So, a formant is just a highlighted frequency created by the interaction of a resonance chamber and a sound wave.

Silly example: You meet someone and their love of pets really "resonates" with you – you both strongly share that love. So, when you are hanging out together, that love of pets becomes stronger (is amplified) – you have it in common, so you do stuff together that has to do with pets. The love you have for pets is the *sound wave frequency*. The love your friend has for pets in the *natural frequency* of the resonating chamber. The increased love of pets when you are together is the *formant*.

There are lots of formants, as there are lots of parts of you, but the there are five that get talked about the most in singing.

The 1st formant is highlighted sound resulting from the interaction of the sound wave with the positioning of the jaw. The more your jaw is dropped, the higher the highlighted frequency is in the sound spectrum. The first formant is around 500Hz (+/-300).

This is important for singing because if the fundamental/pitch is well below the formant range, the quality of the sound is rich, but if the fundamental is above the formant regions the sound is thin. So, on high notes, where the fundamental is already high, we need to increase the highlighted frequency of the formants to keep the tone sounding rich. We can do this by opening our jaw to increase the first fundamental highlighed frequency (so that the pitch is safely below it).

The 2nd formant is the highlighted sound resulting from the interaction of the sound wave with the positioning of the tongue. A higher arched tongue creates a higher highlighted frequency. The second formant is around 1500Hz (+/-800)

Remember, our ears highlight frequencies between 1000 and 5000 Hz, by arching our tongue positiion, we can highlight the second fundamental on the lowest notes and keep it in our ears' happy place. The second formant is crucial in creating the musical theatre sound. Sound spectrums (visual representations of sound) show the strongest peaks at the 2nd formant when singing musical theatre. So, arch your tongues in this style!

The 3rd formant is the highlighted sound resulting fom rounded lips vs unrounded lips and the tip of the tongue position. The third formant is around 2500 Hz. The 4th and 5th formants are determined by vocal tract length, pharynx shape, and larynx shape.

SINGER'S FORMANT

Singers do something cool while singing well – they actually create another formant – one that doesn't exist in speech. It is right around 3000-4000Hz, and creates the "ring" that people associate with great singing. By widening the pharynx and lowering larynx, singers create a new little resonator shape that highlights frequencies in the 3000-4000Hz range – which is delightful because it matches the frequencies that our ears like to highlight. The result is a sparkly, shimmery sound to humans.

The shape is only created through the manipulation of the pharynx and larynx. Without moving them, the pharynx is the opening to the larynx and they function together as one resonator. By changing the shape of the pharynx and moving the larynx down, thay are no longer part of one resonating system because they are each now in different shapes. Boom! Extra, sparkly resonator!

FUN FACT:
Intervals that we hear as pleasing to the ear have really "clean" numerical relations to each other! That's one reason singing exactly on pitch is crucial…

Interval	*Frequency Ratio*	*Examples*
Octave	*2:1*	*220 Hz and 440 Hz*
Third	*5:4*	*220 Hz and 277 Hz*
Fourth	*4:3*	*342 Hz and 256 Hz*
Fifth	*3:2*	*384 Hz and 256 Hz*