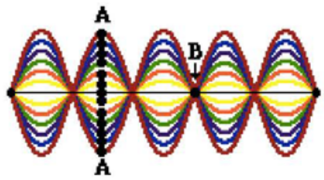
Student 3: Low Merit

NZQA Intended for teacher use only

How to play the saxophone PHYSICally?

We can listen to the deep brass tone of the Alto saxophone because standing waves are created when blowing through the bore of the instrument. Why does a note such as high D sound different from a flute to a saxophone, both in the woodwind family? The answer will become simple once you understand the simple basic concepts. You must have knowledge of standing waves, fundamental and overtones, pitch and timbre before you attempt in answering such questions.

Firstly, we should identify what a sound wave is. It is a longitudinal wave. Energy is transferred parallel to the disturbance through the medium, air, without the actual transport of matter however this creates vibration, a repetitive back-and-forth motion of particles. Due to the longitudinal motion of air particles, there are regions of high pressure, compressions, and low pressure, rarefactions, through the medium. These are annotated through the graph on the right. 'A' high pressure of particles. 'B' represents no disturbance moving through it. As you blow through the saxophone, you are creating the disturbance for the first particle to 'pull' and 'push' the second particle and so on. It is because of this vibration within the bore of the instrument that we can hear it. To make a sound, something needs to vibrate.



How fast the particles vibrate inside the medium over a given time is called the frequency. The reed of the saxophone gives off the disturbance which vibrates the interacting particles at frequency and because they 'push' and 'pull' each other, all the particles in the medium are at that frequency. It is important to note that frequency also measured the amount of compressions and rarefactions because the human ear acts as a detector. We are able to associate these fluctuations of air pressures with pitch, highness or lowness of a note. The higher the frequency, the higher the pitch. One octave lower means the frequency was halved. If your musical instrument is said to be out of tone, this means your instrument is out of pitch and at the wrong frequency. This can be adjusted by pulling and pushing the mouthpiece in which changes the length of the bore ever so slightly. All musical instruments have one or a set of natural frequencies which they vibrate. The timbre, quality, of the sound is dependent on how many natural frequencies there is vibrating. If an instrument like the flute has only one natural frequency when vibrated, the sound is purer. The shape of the wave is

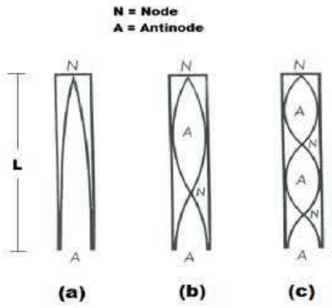
The volume produced by the saxophone can be manipulative to become louder if you blow harder on the saxophone. By blowing harder, you are making the amplitude of the waves bigger. For a wave to have a high amplitude, high displacement of particles, more energy is needed. Therefore, more energy means the sound will carry further. The more you blow, the more the reed moves, and so the more force is put into the saxophone, and thus the more pressure. Pressure is given P=F/A. BOOM

If we want to make a note in a saxophone we have to produce an almost constant frequency. So we have to make a standing wave. A standing wave is produced when a wave travels through the saxophone which is a closed pipe, and the wave bounces back producing resonance. This requires a reflection at the open end. This creates specific points in the medium to appear as if they aren't moving, called nodes. This occurs by a change in impedance at the end of the pipe. This can also be considered from a pressure perspective, where the outside atmosphere pressure does not change but the wave efficiently leaves a 'gap' for the outside air to be fill, and the wave can reflect. Since an external factor essentially drives the vibration, blowing through the instrument, it is classified as a forced vibration and resonance can occur. Only certain frequencies produce resonance thus only certain frequencies produce a standing wave.

Resonance results in a large amplitude, due to the source wave with a certain frequency interfering constructively with the reflected wave. The vibration of the reed from blowing creates several frequencies, several of these will match a natural frequency. Since the waves have the same natural frequency, it is said that the saxophone is forced into a vibrational resonance, and standing waves is formed. Each natural frequency creates a different

standing wave. 'At any frequency other than a harmonic frequency, the interference of reflected and incident waves results in a disturbance of the medium that is irregular and non- repeating.' This rarely happens because objects favor natural frequency with high amplitude due to their minimum energy requirement. Each standing wave corresponds with a harmonic of the instrument, the lowest being called the fundamental frequency. For the saxophone and other musical instruments, these harmonic frequencies are related by ratios and these can contribute to why the saxophone sounds cool. It is important to note that multiple standing waves, all the waves that are travelling back and forth through each other, can be created to make the resultant wave and its pitch. ①

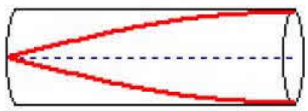
The timbre, quality, of the sound is dependent on how many natural frequencies there is vibrating. If an instrument like the flute has only one natural frequency when vibrated, the sound is pure. The shape of the wave accounts for what the note sounds like, timbre. The shape of the resultant wave results how many harmonic frequencies (and their amplitude). A note such as high D sounds different from a flute to a saxophone because every musical instrument has a different characteristic timbre, each has its own way of creating waves that form different standing waves.



Closed tube - modes of vibration

The saxophone is an example of a closed end pipe; the mouth piece is almost completely sealed by the reed so the pressure is large but there is little air moving through it.
Because at an open end of a pipe the air is free to vibrate, the standing wave will have an antinode. Air particles at the closed end aren't free to move, so is a nodal position. 'Because of the restrictions, the standing wave shapes that can be fitted into the pipes are severely restricted'. They cannot play even harmonics. The harmonic number of a standing wave is the number of times its frequency of the 1st harmonic. In a closed pipe there is no wave that has twice etc., the frequency of the 1st harmonic so these even harmonics do not exist in the saxophone. The saxophone can only play odd harmonics or overtones.

1st Harmonic



The first harmonic has a node and anti-node. The distance between two nodes is half a wavelength. Therefore, the fundamental frequency (diagram on the right) is equal to one quarter of a wavelength. The second harmonic will be double the 1st harmonic, it will be equal to one half of a wavelength. The second harmonic will result in two nodes on either end, this harmonic is not possible however in the saxophone. If a node is present at the open end, the wave will reflect and a sound will not come from the saxophone. Therefore, the odd harmonics can only be heard, the 3rd, 5th etc. harmonic.

Different notes are played by pushing down on notes, they are arranged at different lengths down the bore of the instrument. By pushing down on certain keys, you are playing a certain note. The note is created by the resultant wave, all the standing waves reflecting back and forth in the medium. By slightly altering the keys pushed down, you are a different set of standing waves, a different resultant wave. If you push no keys down, C# is being played as a result of the different number of standing waves. As the saxophone warms up, the increased air temperature results in an increase in the sound velocity. Velocity equals wavelength times frequency. Since the wavelength is fixed, gives an increase to the frequency. ②