Standing Waves

4.3.2 Explain the formation of standing waves in one dimension

When two waves of the same frequency and wavelength travel in opposite directions a standing wave is created. They can also be created when a single wave is reflected off a fixed boundary (string reflecting with one end of the string attached to the wall). It is called a standing wave because it does not appear to move. The peaks become troughs (anti – nodes) and vice versa, but the points with zero displacement (nodes) stay in the same place, i.e. they do not travel.

4.3.3 Compare standing waves and traveling waves

- While traveling waves transmit energy a standing wave does not. However there is energy associated with standing waves.
- Any given point on a traveling wave will have amplitudes ranging from the minimum to the maximum amplitude, i.e. all point can attain any amplitude. Where as a given point on a standing wave will have amplitudes ranging from a max to min, but not necessarily the max and min of the wave…
- The wavelength of a traveling wave is the physical distance from a peak to the next peak or from a trough to the next trough. The wavelength of a standing wave is twice the distance between nodes or twice the distance between antinodes.

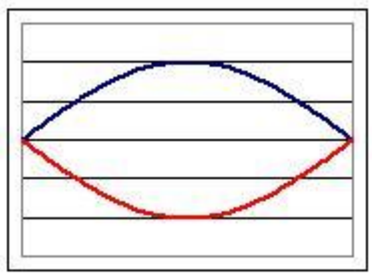
4.3.4 Explain the concept of resonance and state the conditions necessary for resonance to occur

Every object has a "natural frequency" this can be thought of as a frequency that he object "likes to vibrate" at. At the natural frequency of an object the energy of the vibration tends to stay in the object and build up or collect in the object. If an object is forced to vibrate at its natural frequency we call this resonance. Resonance can be observed when you sit in a swing and rock your legs back and forth to generate motion. Sometimes people sing in the shower and they think they sound good… This is because the shower stall has several resonant frequencies, the sound waves build up and sound amplified. The amplified waves make the voice sound richer and just plain better.

4.3.5 Describe the fundamental and higher resonant modes in strings and open and closed pipes

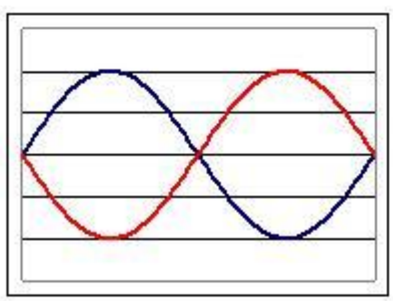
Musical instruments depend on standing waves for their characteristic sounds. Each instrument has different natural frequencies. When a string is plucked or "bowed" the string resonates in such a way as to create a standing wave. If air is blown across the opening of a pipe a standing wave is set up inside of the pipe and a sound is generated.

Strings: Each end of the string is fixed and therefore a node with an antinode in the middle. Since the wavelength is twice the distance between the nodes, the longest wavelength is twice the length of the string. This is known as the fundamental mode or fundamental frequency.

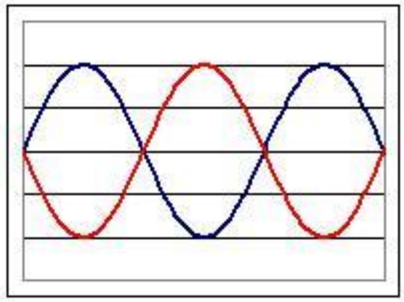


Fundamental Frequency

The string must have a node at both ends of the string, but it could also have a node in the middle of the string. 3 nodes and 2 antinodes generates a wavelength equal to the length of the string.



Second Harmonic Frequency



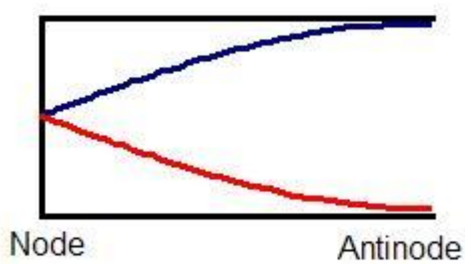
Third Harmonic Frequency

We can also generate a standing wave with 4 nodes and 5 nodes and so on… These other modes or frequencies are called higher resonant modes or higher resonant frequencies. In Theory the string can vibrate at an infinite number of frequencies or wavelengths. In general we can describe the possible wavelengths of a string with the equation:

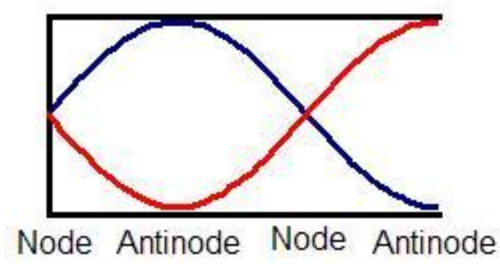
(1)
$\lambda = 2Ln, n = 1,2,3,4...$

Where L is the length of the string and n is the mode. If n = 2 we would say the string is vibrating in the second harmonic, if n =3 third harmonic and so on.

Closed Pipes: If you blow across the opening of a pipe that is closed at one end a sound is generated. The sound is generated by a standing wave. Just like with a string there is a fundamental frequency and higher resonant modes. However with a closed pipe the requirement is that there is a node at the closed end and an antinode at the open end. Why? Sound is generated by moving air, at the closed end the air can not move, i.e. there is zero displacement… At the open end of the pipe there is maximum displacement…



Fundamental Frequency



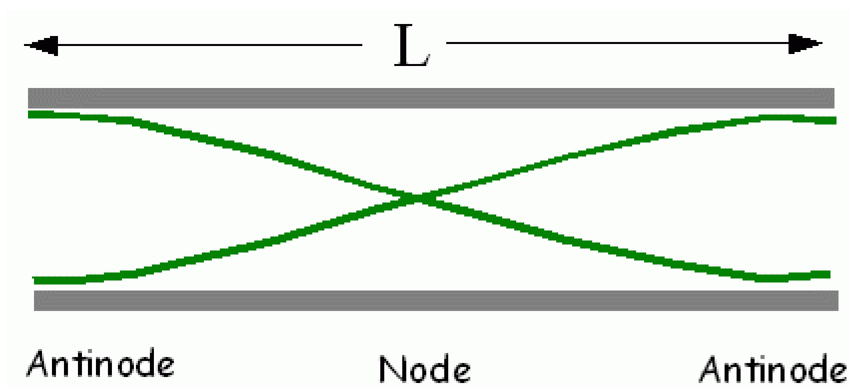
Second Harmonic Frequency

For a closed pipe the wavelength of the fundamental frequency is 4 times the length of the pipe. The second resonant mode has a wavelength of 4/3 times the length of the pipe. In general we can find the wavelength by:

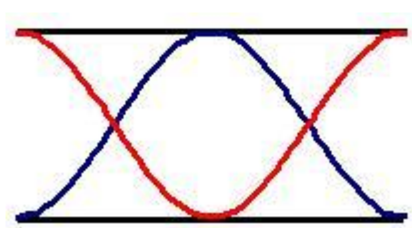
(2)
$\lambda = \frac{4L}{2n-1}, n=1,2,3,4...$

Open Pipe: Just like with a closed pipe an open pipe can support a standing wave. The boundary conditions are that there must be antinodes at both ends of the pipe.

The fundamental frequency occurs when there is two antinodes and one node. The wavelength is 2L. The second fundamental frequency has nodes, and three antinodes.



Fundamental Frequency



Second resonant mode/frequency

Source: http://ibphysicsstuff.wikidot.com/standing-waves