



Exhibit message

One-dimensional standing waves in liquid in a pipe resemble what happens to the air in wind instruments.

Quick Fact

The musical sounds from wind and brass instruments, such as a flute or trumpet, are made by standing waves in air within the instrument pipe.

The human vocal tract also acts like a pipe instrument. Standing waves formed in our vocal tract are responsible for the musical sounds we make when singing.

Graphic panel text

Just as you can see standing waves in strings and on drums, you can also see standing waves in liquid.

To travel or to stand

A **standing wave** is different from a **travelling wave**. A travelling wave appears to move forwards or backwards. You may see a travelling wave when you first begin the vibrations in the pipe. A standing wave, on the other hand, does not seem to go anywhere.

Sound waves in pipes and air

The standing waves in this pipe are similar to what happens when sound waves travel

through the air, or musical sounds form in pipe instruments.

Low instruments

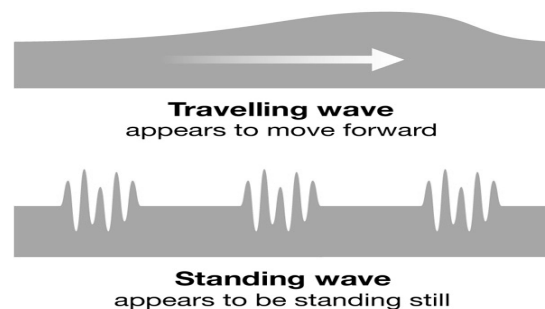
Pipe instruments include flutes, saxophones, clarinets and bassoons.

The **lowest notes** come from the longest instruments.

Want to know more about standing waves in pipes?

A standing wave in the liquid of a pipe is similar to the longitudinal standing waves that form in the air of **pipe instruments**, such as bassoons, trumpets or recorders.

A **standing wave** is different from a **travelling wave**. A travelling wave appears to move forwards or backwards. A standing wave, on the other hand, does not seem to go anywhere.

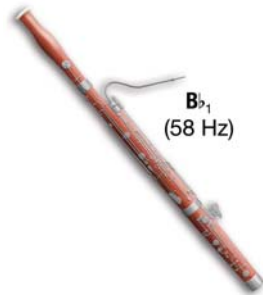


A **standing wave** is the combination of two waves travelling in opposite directions. When a pipe instrument is blown a sound wave is created in the air of the pipe. When the wave reaches the end of the pipe it is **reflected**. This second, reflected wave travels in the opposite direction to the first wave. The two waves collide and **interfere** with each other.

The interference creates areas where the wave is alternatively larger and smaller, called **antinodes**, and areas where the wave remains at equilibrium, called **nodes**. For a given frequency, the nodes and antinodes occur in the same position, making a wave that appears to be standing still.

The number of antinodes appearing in the standing wave depends on the frequency of the wave. High frequencies produce standing waves with more antinodes than low frequencies. The lowest frequency produced by

a pipe is called the **fundamental**. The fundamental frequency corresponds to the note we hear. The length of the pipe determines the frequency of the fundamental. A long pipe is capable of producing a fundamental with a low frequency, while shorter pipes produce higher frequencies. High frequencies are perceived as notes with high pitches while low frequencies are perceived as low pitches.



All instruments depend on **standing waves** to produce their musical sounds. Standing waves occur at the natural (**resonant**) frequencies of an object. Resonant frequencies are easily sustained, so **very little effort creates a lot of sound**. Instruments can be made to produce standing waves with **predictable frequencies**, which correspond to musical notes. In this way, frequencies corresponding to given pitches, or notes, are controllable and reproducible, making music is possible.

Extra for experts

A node is an area of a standing wave that does not vary from the normal (equilibrium) position, and an antinode is an area of maximum variation above and below the equilibrium. There are **two types of nodes and antinodes** in the standing waves of pipes. These are **pressure** and **displacement nodes and antinodes**.

At the **open end** of a pipe, air is able to move freely in and out of the pipe. In a standing wave this will be an area where particles are moving with maximum variation, they are maximally displaced. This is therefore a **displacement antinode**. However, because the particles are able to move freely at this point, the air pressure at this point will not vary from the air pressure outside of the pipe. This is therefore a **pressure node**.

At the **closed end** of a pipe, on the other hand, air cannot move freely. The closed end is always a **displacement node**. This is, however, an area where the air pressure varies

a lot due to maximum interference of reflected waves at this point. This results in a **pressure antinode**.

The **fundamental frequency** of a standing wave in an **open pipe** (that is, open at both ends) will have areas of maximum air movement (displacement antinodes) at both ends and one area of minimal movement (displacement node) in the middle of the pipe. The situation for the pressure nodes and antinodes is reversed. The open ends will be areas of little change in air pressure (pressure nodes) while the air pressure in the middle of the pipe will vary the most (pressure antinode).

Pressure nodes and displacement antinodes always occur at the open end of a pipe, while pressure antinodes and displacement nodes always appear at the closed end of pipes.

Helpful terms

Frequency: The number of times a vibration occurs in one second (hertz or Hz). Fast vibrations have high frequencies and produce high notes.

Pitch: The perceptual phenomenon of how high or low a tone seems. The pitch of a tone corresponds to its frequency. High frequencies are perceived as high tones.

Resonance: The increased vibration and loudness of a frequency that occurs at the natural frequency of an object. The natural frequency is determined by the object's size and the characteristics of the material from which it is made.

Further information

General:

- ✧ *Musical Acoustics, 3rd edition.* D E Hall, 2002. Wadsworth Group (Brooks/Cole), California.
- ✧ *Measured Tones.* I Johnston, 2002. Institute of Physics Publishing Ltd, Bristol, UK.
- ✧ *The Physics of Musical Instruments, 2nd edition.* N H Fletcher and T D Rossing, 1998. Springer-Verlag, New York.
- ✧ *How do woodwind instruments work?* Acoustics Lab, UNSW, Joe Wolfe.
<http://www.phys.unsw.edu.au/~jw/woodwind.html>

Pipes:

- ✧ *Standing sound waves.* Indiana University High Energy Physics course notes, 1999.
http://hep.physics.indiana.edu/~rickv/Standing_Sound_Waves.html
- ✧ *Introduction to clarinet acoustics.* Acoustics Lab, UNSW.
www.phys.unsw.edu.au/~jw/clarinetacoustics.html
- ✧ *Introduction to the acoustics of brass instruments.* Acoustics Lab, UNSW.
www.phys.unsw.edu.au/~jw/brassacoustics.html

Animations:

- ✧ *The Physics of Music to Your Ears: Standing Waves.* Professor F Skiff and A Diallo, 8 November 2003.
<http://www.physics.uiowa.edu/~umallik/advventure/music.htm>
- ✧ *Acoustics and Vibration Animations.* Dr D Russell, 2003.
<http://www.gmi.edu/~drussell/Demos.html>

Basic physics books, such as:

- ✧ *Conceptual Physics, 9th edition.* P Hewitt, 2002. Addison Wesley, Boston, Illinois.
- ✧ *Jacaranda Physics 2.* G Lofts, et al, 2004. John Wiley & Sons, Milton, Qld.

- ✧ *Physics, Principles with applications, 6th edition.* D C Giancoli, 2004. Prentice-Hall, New Jersey.