Exhibit message

Standing waves occur when waves travelling in opposite directions collide, or **interfere**, with each other. The one-dimensional transverse standing waves in a string create the musical sounds of guitars, violins and pianos.

Quick Fact

The strings from the first stringed instruments were made from the guts of animals cut into thin strips.

Graphic panel text

Standing waves in a string

The standing wave has areas that don't move at all (**nodes**) and areas that move a lot (**antinodes**). The 'bumps' in the string are antinodes.

The number of nodes or antinodes depends on how fast the string is vibrating (**frequency**). The more you see, the faster the string is vibrating (higher frequency).

String features

A string vibrating at its **slowest (fundamental) frequency** has only one 'bump' (antinode). This matches the **lowest note** the string can make.

A string can also vibrate 2, 3, 4 or more times faster than the slowest frequency. Higher frequencies show more nodes and antinodes.

Long and low

Longer strings produce lower notes. The lowest possible note (fundamental frequency) a string can make depends on its length.

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

Nodes (areas which don't move at all) always occur at the fixed ends of a string.

Want to know more about standing waves in strings?

Standing waves occur when waves travelling in opposite directions collide, or **interfere**, with each other.

When the string is plucked a wave travels to the fixed end of the string and is reflected back. This second, reflected wave travels in the opposite direction to the first. The two waves collide and cause **interference**.

The interference can cause the wave to get larger (**constructive interference**) or smaller (**destructive interference**) at certain points. On a string, areas of constructive interference form **antinodes** and areas of destructive interference form **nodes**.

The string moves the most at the antinodes and doesn't move at all at the nodes. Nodes always occur at the fixed ends of the string, and can also occur throughout the middle of the string with the antinodes in between. The antinodes are seen as the 'bumps' in the string.

A standing wave appears to be standing still because it has a regular pattern of areas that are moving a lot (**antinodes**) and other areas that are not moving at all (**nodes**).

The number of antinodes (bumps) on a string corresponds to the **frequency** of the standing wave. The more antinodes you see, the higher the frequency. A string vibrating with only one antinode is vibrating as slow as it can, at its **lowest frequency**. This is called the **fundamental frequency** and corresponds to the lowest pitch, or note, the string can make.

The **length** of a string determines the lowest frequency, and hence the lowest pitch, it can have. Longer strings vibrate at lower fundamental frequencies, and therefore produce lower pitches.

A string can also vibrate 2, 3, 4 or more times faster than the fundamental frequency. **Higher frequencies** show more antinodes (and nodes). For example, a string vibrating at twice the fundamental frequency shows two antinodes (bumps) and three nodes; a string vibrating at three times the fundamental frequency shows three antinodes.

These other higher frequencies produce higher pitches and are called **overtones**. Overtones are present at the same time as the tone of the fundamental frequency. While the main note heard from an instrument is due to the fundamental frequency, the overtones add to the characteristic quality of each instrument. This quality is called ***timbre*** (pronounced 'tom-ber') and is different for every instrument. Different instrument timbres allow us to distinguish the sound of a guitar from that of a piano or a violin.

Extra for experts

The length of a string determines the lowest possible frequency (fundamental frequency) at which it can vibrate. This, in turn, corresponds to the lowest note the string can produce.

The frequency of a wave is related to the speed of the wave and to the wave's **wavelength**. Long wavelengths correspond to low frequencies. The wavelength of a wave is the distance between two crests, troughs or similar phases.

The wavelength corresponding to the fundamental frequency for any string can be determined by its **length**. Once we know the wavelength and the speed of the wave, we can calculate the frequency of the fundamental, and therefore determine the lowest note any length of string can produce.

The length of the wavelength (λ) of the fundamental frequency is twice the length (L) of the string. This is shown in the equation as: $\lambda = 2L$. So, if a string was 60 cm long it would have a wavelength corresponding to the fundamental frequency of 120 cm (1.2 m) long.

In other words, for the fundamental frequency the length of the string is ½ the wavelength. For the second harmonic (two times fundamental frequency) the length of string is 1 wavelength. For the third harmonic (three times fundamental frequency) the length of string is 1½ wavelengths, and so on.

The frequency (f) of a wave can be calculated as the dividing the speed of the wave (v) by the wavelength (λ), as represented by the equation: $f = v/\lambda$.

The **speed** of a transverse wave in a string is determined by the tension, thickness and material of the string.

Increasing the tension in a string by tightening it, increases the speed with which the wave travels along it and therefore increases the frequency of the vibration. In contrast, waves travel more slowly along thicker strings, which means thicker strings vibrate at lower frequencies and produce lower notes.

For any given length and thickness of string, you can change its pitch by tightening or loosening it.

Helpful terms

Frequency: 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 pitches while low frequencies are heard as low pitches.

Harmonic: An overtone that is a whole number multiple of the fundamental frequency. All harmonics are overtones, but not all overtones are harmonics.

Note: A single musical sound of definite pitch.

Overtone: Frequency produced by a note from a musical instrument that is above the fundamental frequency. May be a whole number multiple of the fundamental frequency or not.

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 pitches while low frequencies are heard as low pitches.

Timbre: The distinctive mixture of overtones that gives the characteristic quality to instruments.

Tone: A note made up of one frequency only, that is, containing no overtones.

Vibration: A single object or particle moving backwards and forwards (or up and down) rapidly.

Further information

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