Waves in a Spring

Exhibit message

This exhibit demonstrates transverse (light and water waves) and longitudinal waves (sound waves). However, being an exhibition about music, the graphics focus more on the sound waves.

Sound energy travels through a liquid or solid medium as a longitudinal wave. Our ear detects sound waves and our brain interprets them as sound.

Quick Fact

The idea that sound travels in a wave-like fashion, spreading out in all directions from its source, was first proposed by one of Julius Caesar's military engineers, Marcus Vitruvius Pollio, over 2000 years ago. His works were rediscovered during the Renaissance period (1500 years later) when scholars verified his ideas. They established that sound must have **some medium** in which to travel and that it is only a wave of **localised disturbance** that travels, not the medium itself.

Graphic panel text

A sound is born! Longitudinal waves

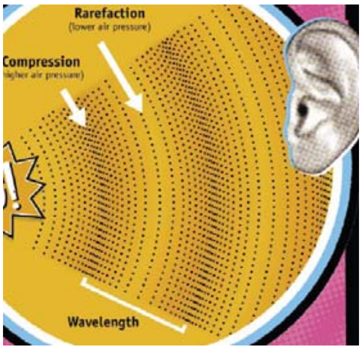
The top spring is a model of a sound wave or **longitudinal** wave.

Imagine plucking a guitar string. As the string vibrates (moves back and forth), air particles near the guitar start to vibrate with tiny changes in air pressure. Each vibration pushes surrounding air particles, causing them to push on the next particles, and so on.

At first, the air particles are pushed closer together as **compressions** with higher air pressure. Then, the air particles spread apart as **rarefactions** with lower air pressure.

Your ear detects the tiny changes in air pressure and your brain recognises these waves as sound.

When the spring coils or air particles move back and forth along the same line as the wave itself, it is called a **longitudinal** wave.

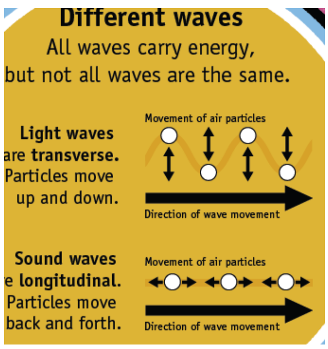


Water and light—transverse waves.

The lower spring that seems to wobble up and down is a model of a **transverse** wave.

You can see transverse waves as ripples on the surface of a pond or a bowl of water. If you watch a cork or a leaf floating on water, you will notice that the cork bobs up and down, rather than move quickly across the water the with a wave. Even though a transverse wave moves **up** and **down**, the wave of movement travels **along** the spring.

Light waves are also transverse waves.



Want to know more about sound waves?

The sounds that we hear around us are the result of sound waves travelling through air. A **sound wave** is a wave of energy created by the disturbance of air around a vibrating source. A **sound** is the brain's interpretation of the ear's detection of sound waves.

Every sound wave begins with a **vibrating object** disturbing the surrounding media – whether it is air, water or solid. A vibrating object is one that is moving backwards and forwards or up and down over and over again. Many every day objects can be made to vibrate. Even if the vibration of the object is not visible, the vibration sets up a travelling wave.

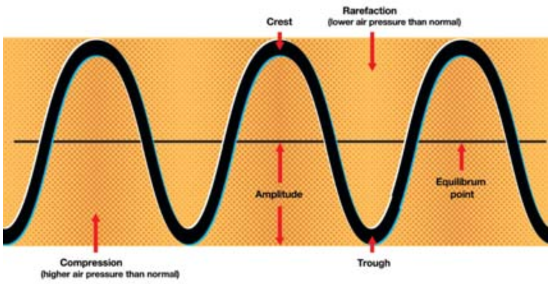
Each vibration pushes and pulls surrounding air particles, passing energy to them and causing them to bunch up. These particles then push and pull the next particles, and so on. Energy is passed from particle to particle, and this energy travels away from the vibrating source in a **wave**.

Although the energy moves outward from the source in a wave, each air particle only moves a short distance. In sound waves, the particles move parallel to the wave direction (backwards and forwards). This is called a **longitudinal wave**.

The **sound wave energy** moves out in all directions from the source. Energy of the wave decreases as it moves further from the source as the energy is being spread over an increasingly large area. Hence, the further from the source one is, the weaker the sound will be.

Other types of energy, such as light energy, also travels in waves. However, light travels in a transverse wave. A transverse wave is different from a longitudinal wave. In a transverse wave particles move up and down on the spot, like people doing the Mexican wave at a football game. Particles in a longitudinal sound wave are more like people bumping into each other in a line. Waves in deep water, such as waves in the ocean, travel in a combination of transverse and longitudinal waves.

In a sound wave in air, areas of the wave where the particles squish up are called **compressions**. These areas have a higher air pressure than normal. They are usually represented as the **peaks** of a transverse wave on a graph. Areas where the particles are spread out are called **rarefactions** and have a lower pressure than normal. Rarefactions are usually represented as the **troughs** on a graph.



The **number of vibrations** the wave makes in one second, that is, the number of complete wave cycles from compression to compression, is called the **frequency**. If the wave completes 200 cycles per second, it has a frequency of 200 cycles per second, or 200 hertz (Hz). The frequency of the wave determines what pitch the sound will have. High frequencies are heard as high pitches. Low frequencies are heard as low pitches.

The **size of the compressions** in a sound wave determines how **loud** that sound will be. The larger the compression (higher air pressure), the louder the sound. This would be represented on a graph by a change in the **amplitude** of the peak and trough. Larger amplitudes represent higher air pressure and therefore louder sounds.

Extra for experts

Sound waves must have some sort of **medium** in which to travel. Sound waves cannot travel in a vacuum. A vacuum is the absence of anything, even gas. Air contains gases, like hydrogen, oxygen, nitrogen and carbon dioxide and so is not a vacuum and can therefore carry sound waves. Sound can also travel in liquids, such as water, and solids, such as metal.

Sound waves travel at different speeds in different media. The speed generally depends on the density and elasticity of the medium. Sound tends to travel faster in denser, more elastic media. For example, sound waves travel faster in water than air and faster through metal than water.

However, although warm air is less dense than cool air, sound waves travel faster in warm air. This is because the air particles are moving more and collide more often and can therefore pass on a disturbance from one particle to another more quickly. The speed of sound in dry air at a temperature of 20ºC and atmospheric pressure is 344 m/s. All sounds, whether high or low in pitch, travel through the air at the same speed.

Helpful terms

Amplitude: The distance of the wave crest or trough from the equilibrium point. Note: the crest of a transverse wave in a graph corresponds to the compression of a longitudinal sound wave.

Compression: Area of a longitudinal wave where particles are more squished up and pressure is therefore higher than normal.

Frequency (f): The number of times a vibration occurs in one second (hertz or Hz). Fast vibrations have high frequencies and produce high notes or pitches. $f = 1/P$

Period (P): The length of time required to complete one cycle of a wave. $P = 1/f$.

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.

Rarefaction: Area of a longitudinal wave where particles are more spread out and pressure is therefore lower than normal.

Sound wave: Longitudinal waves of air pressure differences caused by a vibrating source and travelling outwards from that source.

Sound: The brain's interpretation of sound waves detected by the ear.

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

Wave: A disturbance travelling outwards in all directions from a vibrating source. It is important to note that the individual particles that the wave is travelling through do not travel with the wave, but are disturbed in a local area only.

Wavelength (λ): The distance between one wave crest, trough or matching phase and the next one. Waves with longer wavelengths have slower frequencies. $\lambda = vf$ (where v = speed of wave)

Further information

- *Musical Acoustics: 3rd edition*. D E Hall, 2002. Wadsworth Group (Brooks/Cole), California.
- *Acoustics FAQs*. Campanella Associates, 2004. www.campanellaacoustics.com/faq.htm#basic
- *Acoustics Animations*. Dr Dan Russell, , 2002. Kettering University Applied Physics, Michigan. www.kettering.edu/~drussell/demos.html
- *Basics in music acoustics*. Acoustics Lab, UNSW http://www.phys.unsw.edu.au/music/basics.html
- *Measured Tones*. I Johnston, 2002. Institute of Physics Publishing Ltd, Bristol, UK

Basic physics texts, 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.
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