

Fundamentals of Sound

What is sound?

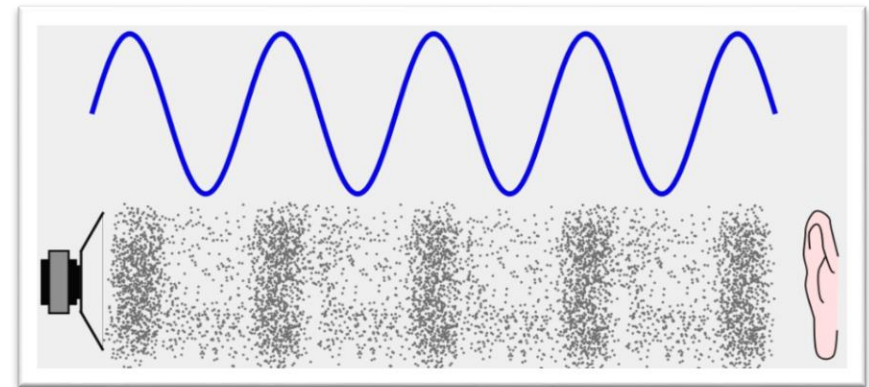
Any sound, whatever it may be, is caused by something vibrating. In other words, by something which is moving back and forth, either in a regular manner or in a random manner, about the position it occupies when at rest. The source of the sound may be a car engine, a burglar alarm or a bird singing. Whatever it is, some part of it must be vibrating for it to produce sound.

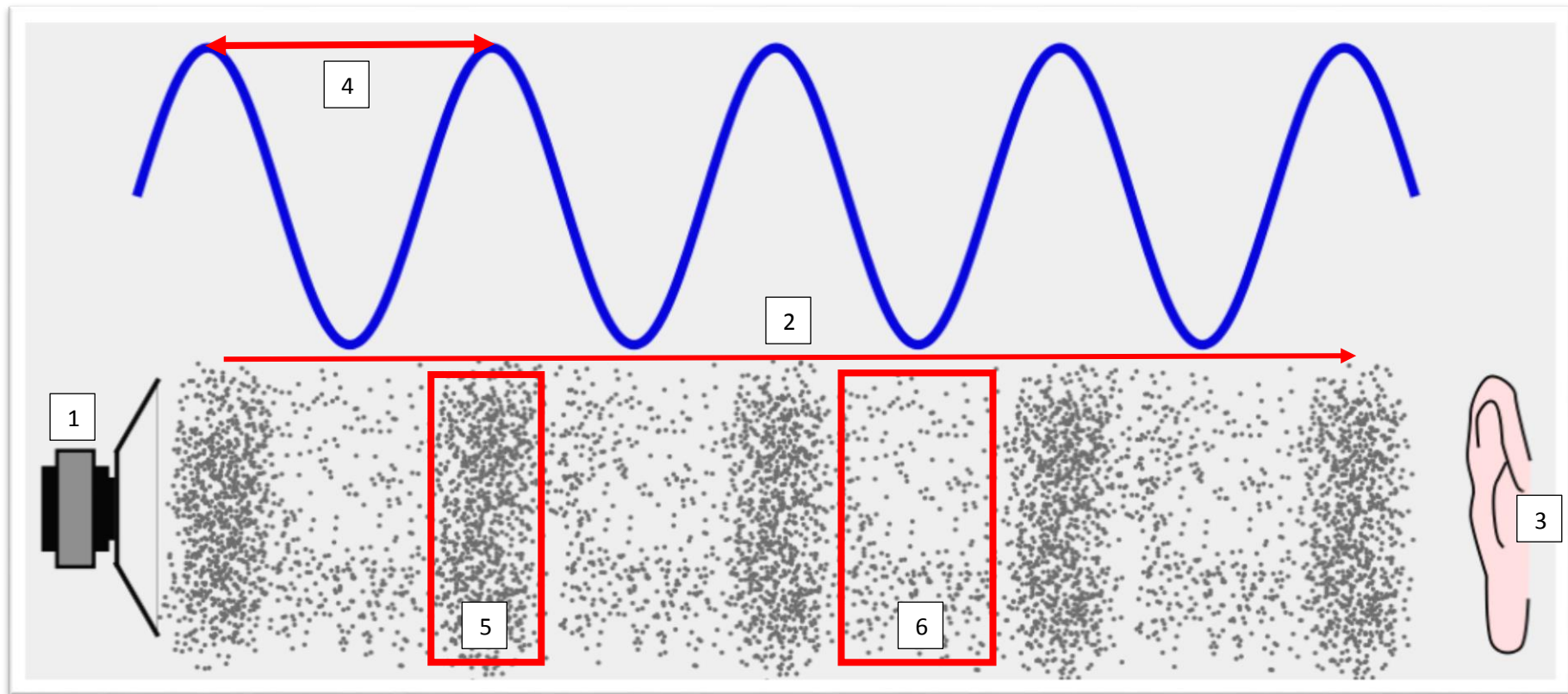
In fact, it is easy to detect the vibrations of many sources of sound. If you touch your throat while singing or speaking, you can feel the vibrations of your vocal cords. Similarly, a hi-fi loudspeaker vibrates strongly especially when the volume is turned up. By lightly touching the speaker cone, you can feel its vibrations as a tingling sensation in your fingertips.

For such vibrations to be heard as sound, there must be a medium through which they can travel from the vibrating source to the ear. For example, sound travels clearly through water, as any swimmer can testify, and it also travels exceptionally well through metal. Most of the sounds we hear, however, are transmitted through air.

The vibrations of a sound source cause the neighbouring air molecules to be alternately squeezed together and pulled apart. These air molecules then push and pull against their neighbours which, in turn, push and pull against their neighbours.

In this way, a series of compressions (regions of higher pressure) and rarefactions (regions of lower pressure) is generated which travels away from the vibrating source. This sequence of pressure fluctuations is what we refer to as a sound wave.





1. Sound source. (Anything that vibrates)
2. Vibrations. (Travelling through a medium)
3. Listener. (Any thing that can sense vibrations)

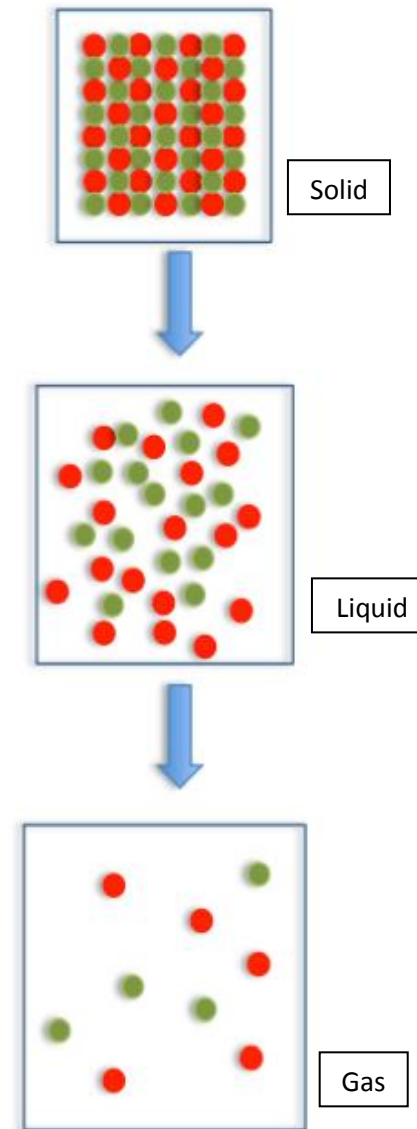
4. One Cycle (AKA One Wavelength)
5. Compressions (High density)
6. Rarefactions (Low density)

The Speed of Sound

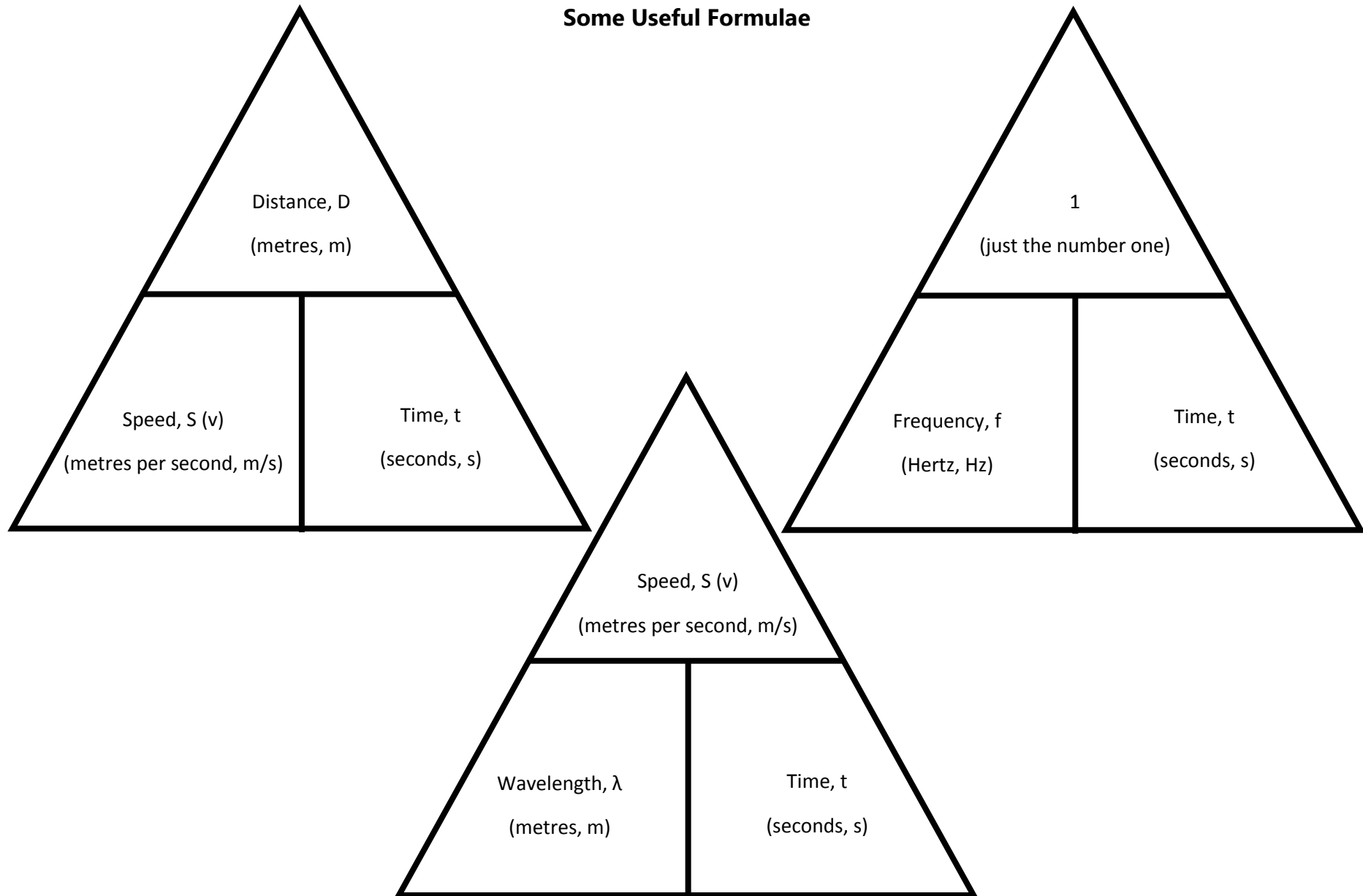
Sound waves travel through different mediums at different speeds. At sea level, sound waves travel through the air at about 760 mph—about five miles a second—which means you can hear nearby sounds almost instantaneously. But they move through water 4 times that fast and through steel more than 17 times as fast.

Medium	Speed of Sound
Rubber	40 - 150 m/s
Air at 40C	355 m/s
Air at 20 C	343 m/s
Lead	1210 m/s
Sea Water	1531 m/s
Gold	3240 m/s
Glass	4540 m/s
Copper	4600 m/s
Aluminium	6320 m/s
Diamond	12000 m/s

Next time you're in a thunderstorm, count the number of seconds that pass between a flash of lightning and the crack of thunder that follows it. Divide that number by three, and the resulting number will tell you roughly how many kilometres away you are from where lightning just struck.



Some Useful Formulae



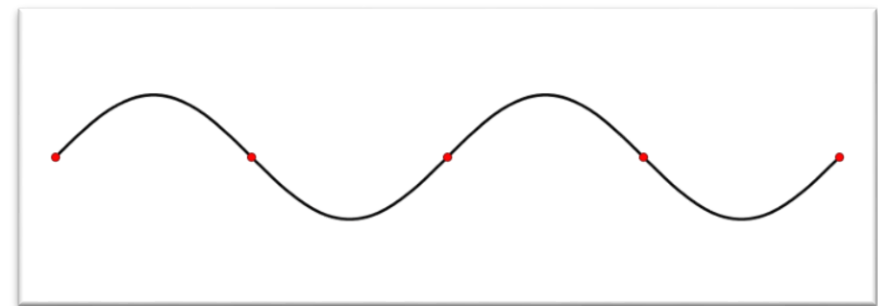
Standing Waves

A standing wave is a particular kind of wave that can only be created when a wave's motion is restricted to a finite region. To understand exactly what this means, let's focus on a vibrating guitar string. The guitar string's motion is restricted on both ends of the string: on the fretboard by your finger on one side and by the bridge on the other side, where it attaches to the body of the guitar. When the string is plucked, the wave reflects off each of these boundaries. The wave's energy quickly spreads out as it repeatedly moves back and forth between the two ends of the string. Through a complicated process of interference, standing waves are produced.

A standing wave gets its name from the fact that it does not appear to be traveling from one side of the string to the other. Rather, it is waving while it stands in place.

Even though the string is only fixed in place at the ends so the entire middle can vibrate freely, you can see that there are some points on the string that are not moving at all. These stationary points on a standing wave are called nodes.

The standing wave shown has three nodes; we only count the untethered stationary points, not the endpoints, of the string where it is being held down. The points that are halfway between two adjacent nodes, where the motion of the string has the greatest deviation from its unplucked position, are called antinodes. The wave depicted has four antinodes - a standing wave always has one more antinode than its number of nodes.

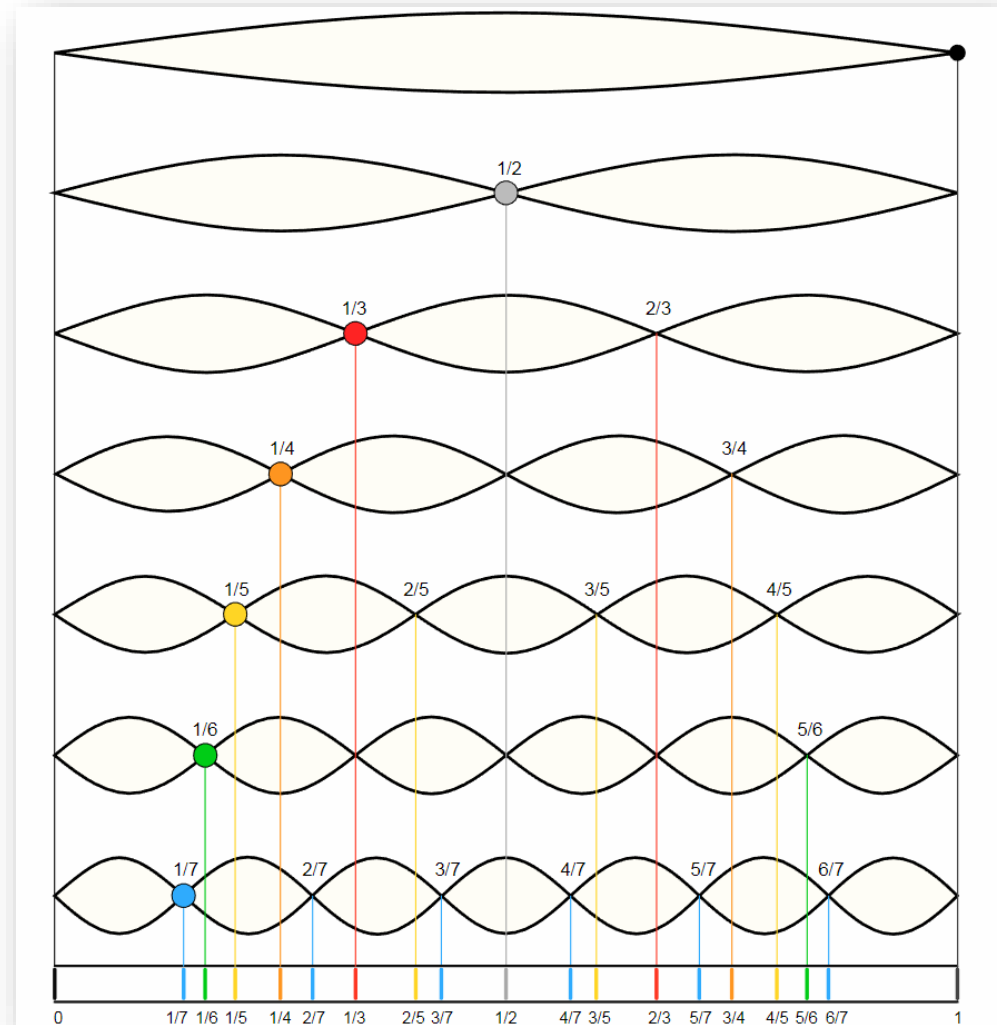


The Harmonic Series

A harmonic is one of an ascending series of sonic components that sound above the audible fundamental frequency. The higher frequency harmonics that sound above the fundamental make up the harmonic spectrum of the sound. Harmonics can be difficult to perceive distinctly as single components, nevertheless they are there.

Harmonics have a lower amplitude (volume) than the fundamental.

Harmonics are positive integer (whole numbers) multiples of the fundamental. For example, if the fundamental frequency is 50 Hz (also known as the first harmonic) then the second harmonic will be 100 Hz ($50 * 2 = 100$ Hz), the third harmonic will be 150 Hz ($50 * 3 = 150$ Hz), and so on.



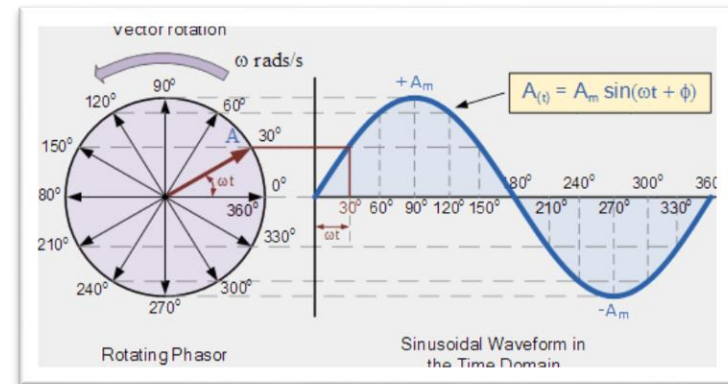
Phase

Phase denotes a particular point in the cycle of a waveform, measured as an angle in degrees. It is normally not an audible characteristic of a single wave (but can be when we use very low-frequency waves as controls in synthesis). Phase is a very important factor in the interaction of one wave with another, either acoustically or electronically.

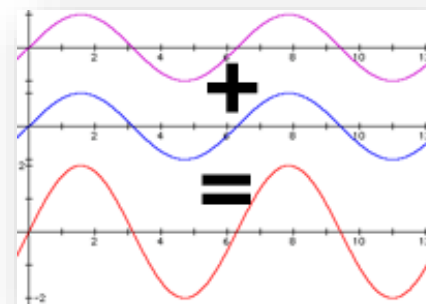
When waveforms of either the same or differing phases are combined, they interfere with each other, and their instantaneous amplitudes are summed to create a new composite wave. This is a fairly simple-to-predict process with electronic circuits, but is far more complex in the realm of sound.

For waves of differing phases, the fraction of a period between peaks is the phase difference and is also expressed in degrees, as above with the sine and cosine waves. Two waves with the same frequency and phase will combine to create a single sound of greater amplitude—this is called constructive interference.

Two identical waves 180 degrees out of phase will completely cancel each other out in a process called phase cancellation or destructive interference.



Go to [Phase Rotation Angle](#) to see how the phase angle changes with time.



'In Phase', 0° or sometimes 360°

180° out of phase

