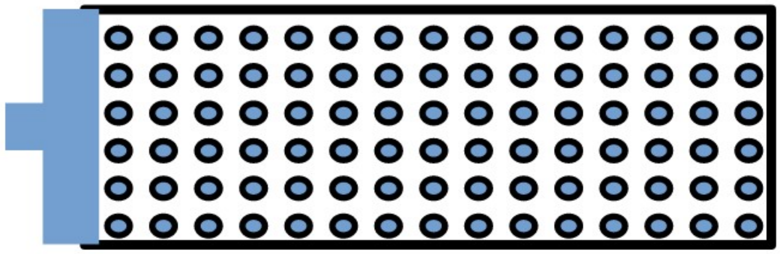
13.3.2: Longitudinal Waves

Longitudinal Waves

These waves are a little more difficult to visualize, though the fundamental ideas are the same as for transverse waves. Amplitude is still the displacement from the equilibrium, wavelength is still the distance between two identical points on the wave, and period is still the time for one cycle to complete. The wave speed is still written as the product of wavelength and frequency. The difference lies in the behavior of the atoms. In longitudinal waves, the atoms of the medium move parallel to the direction that the energy is transported.

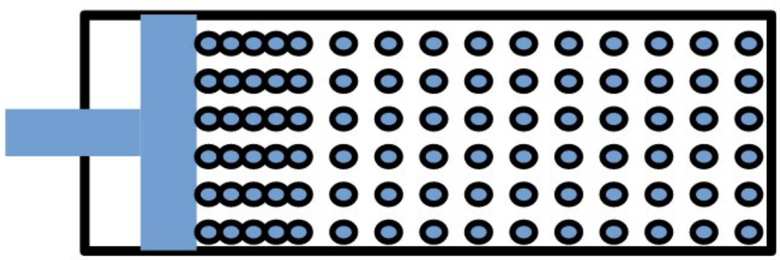
The atoms have some sort of average spacing when they are in equilibrium. A force can act on them to cause them to move, pushing them closer together or pulling them apart than the equilibrium spacing. The regions where the atoms are forced closer together are called *compressions* and the places where they are pulled further apart are called *rarefactions*. Because of this atomic behavior, these types of waves are also called compression waves.

The image shows the top view of a cylindrical 'tube' of air. There is a moveable piston at the left end of the cylinder. Initially, the piston is stationary and the density of the gas is 'normal' so the gas atoms have a certain average spacing.



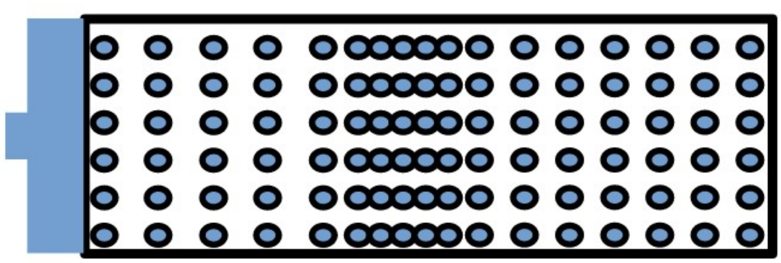
Ideal gas in equilibrium, by Claude Mona, under CC BY NC

When the piston is moved to the right, it exerts a force on the nearest atoms, causing them to move closer together and making them move away from the piston. These atoms collide with the next nearest atoms, causing them to move and so on. Although each atom doesn't move very far, the compression region travels away from the piston.



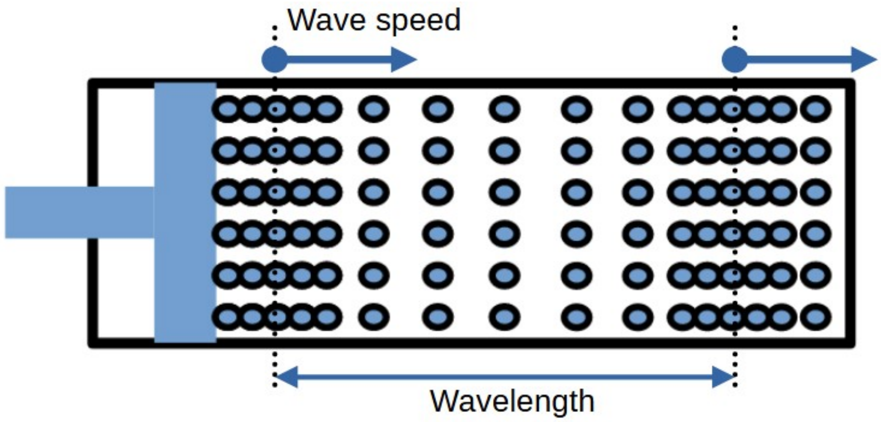
Ideal gas under compression, by Claude Mona, under CC BY NC

When the piston is retracted, it drags the nearest atoms 'backwards' pulling them further apart and forming a rarefaction. The region of rarefaction also moves along the tube.



Ideal gas rarefaction, by Claude Mona, under CC BY NC

When the piston compresses the gas for the second time it has returned to its initial position, completing one cycle. The first compression region has traveled some distance during this time, so the distance between the first and second compressions defines the wavelength.



Compression wave, by Claude Mona, under CC BY NC

You can easily create compression waves with a long coiled spring like a slinky. Take a slinky and stretch it along a horizontal surface. Notice how far apart the coils are when the slinky is in an equilibrium state. Have someone hold one end of the slinky stationary while you rhythmically push and pull on the other end. After a little while you'll notice that there are sections of the slinky where the coils are closer together and sections where the coils are farther apart than when the slinky was stationary. The locations of the compressed areas travel along the slinky.

You can find many youtube videos and virtual physics demonstrations (phet.colorado.edu/en/simulations/waves-intro) illustrating these types of compression waves. The side to side shaking that happens in an earthquake is the result of a longitudinal wave, as is the sound wave produced by the movement of a speaker cone or the vibration of a guitar string. The points of compression and rarefaction will be linked to high and low air pressure regions in sound waves.