Speed of sound

**Objective:** Describe what produces sound and how sound propagates through a solid; know how the speed of sound in a solid is related to its atomic “spring stiffness” and the mass and diameter of an atom; apply the momentum principle to a ball situated between two springs; apply the momentum principle to a ball situated between two springs that are attached to other balls.

**Modeling the propagation of sound in a solid**

We have modeled a solid as balls (atoms) connected by springs (interatomic bonds). This is a useful model for explaining various experiments with solids. For example, if you have a metal rod and you strike one end with a hammer. The strike will cause the atoms on that end to vibrate. These interact with atoms next to them in the lattice, causing them to vibrate. And those atoms interact with the atoms next to them to...you get the picture. Eventually, after some measurable time interval, the disturbance at one end of the rod propagates to the other end and causes those atoms at the other end to vibrate. The speed that the disturbance propagates from one end to the other end is called the speed of sound in the solid.

Sound is caused by vibration. Your ear detects sound because moving air collides with your ear drum causing it to vibrate. A drum head produces sound as it vibrates; a speaker cone produces sound as it vibrates; a reed produces sound in a saxophone by vibrating. The disturbance then propagates through a medium such as air, water, or aluminum, for example. The speed of sound—how fast the disturbance propagates—depends on properties of the medium. It is different for a gas, liquid, and solid.

In the case of a solid, the speed of sound depends on the stiffness of the interatomic bonds, the diameter of the atoms, and the mass of the atoms. The speed of sound in a solid is

\[ v = \omega d \]  

where

\[ \omega = \sqrt{\frac{k_s}{m}} \]  

The stiffer the bonds, the higher the angular frequency of oscillation of an atom, and, therefore, the greater the speed of sound (speed of propagation of a disturbance) in the solid.

**Application**

1. What is the speed of sound in copper? Its molar mass is 27 g/mol and its density is 8.92 g/cm\(^3\). Its Young’s modulus is \(13 \times 10^4\) N/m\(^2\).