Thermodynamics & Statistical Mechanics PSet 1

1. **Book Problems:** 1.5, 1.8, 1.12, 1.16, 1.24

2. **Stability, Sound, and Universality** Many of the macroscopic properties of objects are *universal* – they do not depend much on the microscopic details. Another word that's used for this phenomenon is 'emergence', as in 'simple macroscopic properties emerge from different, complicated microscopic physics'. Perhaps the simplest version of this phenomenon is sound (note that quanta of sound are called 'phonons', as quanta of light are called 'photons').

   Solids maintain their shape when you push or pull on them, ie they are *stable*. So let's imagine an infinite one-dimensional row of molecules connected to their nearest neighbors by molecular bonds to form a solid. As a function of the separation x between a pair of neighboring molecules, what does the potential $V(x)$ look like? If you assume that $x = a$ is the minimum of this potential, what's the simplest approximation for $V(x)$ for small displacements $\delta x = x - a$? Qualitatively, what happens if you pull an atom out of place and let it go? Given that the molecules in the 1-d chain have mass m and $V''(a) = k$, estimate the speed of sound in this solid. Note that none of the other details concerning the molecules are relevant here.

   For extra credit, show explicitly that your estimate is correct by finding sound-wave solutions to the equations of motion of (all) the atoms in the chain.

   You should also think about why sound propagates in liquids and gases. What properties would a 'material' need to have to fail to carry sound waves? Can you think of any examples?

3. **Book Problem Extra Credit:** 1.15, 1.17, 1.22