ASSIGNMENT 4

Due: 1 October 2003

Problems:

1. For a linear elastic chain, show that the effective force constant for transverse vibrations is much less than that for longitudinal vibrations. Hint: Resolve the elastic force on an atom into orthogonal components.

2. Consider a linear elastic chain of atoms. Let there be a nearest-neighbor interaction with force constant C_1 and a 2^{nd} nearest-neighbor interaction $C_2 = \frac{1}{2} C_1$. Derive the resulting dispersion relation and make a sketch, labeling extremal frequencies.

3. Consider longitudinal vibrations of a diatomic chain of atoms with interactions given by a single force constant C. (a) Calculate the phase velocity for the acoustic modes near k = 0. (b) show that for optical modes, the different atoms move in opposite directions (i.e. show that the ratio of displacement amplitudes u/v is negative). (c) Show that at $k = \pi/a$, the limiting frequency of the acoustic mode involves only M_1 and that of the optical mode only M_2 (assume $M_1 > M_2$). To demonstrate this, consider explicitly the behavior of u/v here.

4. Calculate the Debye temperature of bcc tungsten (density 19300 kg/m^3 and a=0.315 nm) from its ultrasonic (~1 MHz) sound velocities (W has nearly isotropic elasticity):

V_L = 5200 m/s and V_T = 2900 m/s.

If we compare this calculation with the Debye temperature obtained from analysis of specific heat data, in what temperature region should we expect agreement? Give your reasoning.