# Physics 240B: Homework Problem Set 3
Due: January 30, 2008

**1. Table Salt: Food for Thought.** 25 points.
The bulk modulus of sodium chloride is $2.4\times10^{11}$ ergs/cm$^3$, and the fcc lattice constant is 5.65 Å.
(i) From these facts, but simplifying considerably by considering NaCl to be described simply by a nearest neighbor spring constant $C$, estimate the value of $C$.
(ii) From this value obtain the frequency of the optical phonon mode (at $k = 0$), and the speed of sound. You may use a 1D model here, but evaluate the resulting expression specifically for NaCl.

**2. Debye Model in 2D.** 25 points.
Consider the Debye model of a simple square lattice (one atom/cell) in two dimensions: $\omega_k = c|\vec{k}|$ independent of direction and polarization.
(i) Calculate the Debye wavevector $k_D$.
(ii) Calculate the density of phonon modes $D(\omega)$. Do this also for 1D, and compare the results for 1D, 2D, and 3D.
(iii) Write and simplify the expression for the heat capacity, for 2D. Carry out the approximations as done in the text to obtain $C_V$ at low temperature, including the constants (you do not need to evaluate, or look up, a remaining integral). Contrast the result with what was obtained in 3D.

**3. Quasi-2D Material.** 10 points.
Consider the limit for a layered 3D crystal, where the forces between layers become weaker and weaker so that it approaches a set of (almost) noninteracting 2D layers. One implication is that the $c_3$ sound velocity gets very small (compared to $c_1, c_2$ which remain 'large'). Describe in words (and simple expressions where helpful) what happens to the heat capacity in this limit. Take into account the results of Problem 2 and the corresponding 3D results.