Midterm Exam: Solid State Physics 476
Oct. 23, 2006

One cheat sheet, double sided. Point values are given with each question. Total midterm is worth 40 points with 4 available bonus points.

1. (a) What is a lattice? What is a Bravais lattice? Give an example. (3)
   (b) What is the difference between a primitive and non-primitve lattice? If there was a choice why would you sometimes choose the non-primitive lattice? (3)
   (c) Sketch the 2-D rectangular lattice. Is it a 2-D Bravais lattice? Sketch in the symmetry operations for 2-D rectangular lattice. Are these symmetry operations point groups? (5)
   (d) Now add a basis atom at x, y (positions in terms of the lattice coordinates such as $\frac{1}{4}, \frac{1}{4}$). Pick any one of the above symmetry operations that you sketched in and show how atom at the general position is transformed. (We did this with a glide transform on the assignment. By adding the basis we have gone from a Bravais *lattice* to something that can be classified as a plane *group*.) (3)

2. (a) Give two of the limitations of using the Bragg formulation of scattering versus the Laue form. (2)
   (b) Suppose that you have an orthorhomic Bravais lattice with lattice constants a, b, and c. What are the lattice vectors and what are the reciprocal lattice vectors? (Show the details of one calculation.) What is the shape of the Brillouin zone? (4)
   (c) Suppose that you attach a two atom basis at 000 and $00\frac{1}{2}$. Calculate the structure factor and comment on the appropriate values that l must take to see reflections. What is term/word/expression applied to the missing reflections? (i.e. *we say they are ...*) (4)
   (d) We observe a reflection with $|\vec{G}| = 2.5$ Å^{-1}. The scattering angle is 60°. Assuming elastic scattering, what is k_i? (You don't need to include a diagram but you might find it useful.) (4)
   (e) What is the standard technique used for determining crystal structures of polycrystalline samples? (2)

3. Consider a 1-D chain of atoms. Let their displacement from equilbrium be given by $u_s(t)$ where s is the atom label. There are N atoms each separated by a. The mass of the atoms is m and treat the atoms as though they are connected by springs with spring constant k.
   (a) Give the form of $u_s(t)$ that describes a travelling wave with wavevector K and frequency ω. Please show this is as a function of s. (2)
   (b) How does this form satisfy periodic boundary conditions? How is it consistent with each atom being equivalent? (4)
   (c) Give a sketch of the 1-D dispersion relation. You don't need to give the functional form but do indicate what range of K is physically relevant (i.e. what is the repeating unit in reciprocal space?) (4)

4. Bonus: Using the Dulong-Petit law estimate the specific heat of gold per unit mass if the molecular mass of gold is 0.197 kg/mole. $k_B = 1.38 \times 10^{-23}$ J/K, $N_A = 6.02 \times 10^2 3$ (4)