

Name:

Exam 1 - Solid State Physics - Fall 2014

October 13, 2014

6:30-8:20PM

Directions: Please clear your desk of everything except for pencils and pens. The exam is closed book, and you are not allowed calculators or formula sheets. Leave substantial space between you and your neighbor. Show your work in the space provided on the exam. I can provide additional scratch paper if needed.

The entire exam is out of 100 points with each question (1,2,3,4) being worth 25 points.

1. **Short answer section**

(a) What is a typical Fermi energy of a metal in electron volts and $k_B T$?

(b) How does the specific heat in metals depend on temperature?

(c) What is a Wigner-Seitz cell?

(d) What is the form of the tight binding wave function?

(e) Write down the Boltzmann equation within the relaxation time approximation.

2. Lattices

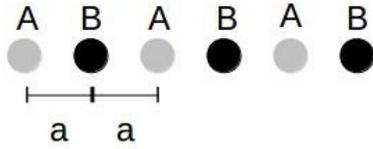
- (a) Many elements including gold and aluminum have an FCC lattice. Sketch an FCC lattice. If a is the length of a side in the underlying cubic lattice, give a set of basis vectors for an FCC lattice.
- (b) What is a reciprocal lattice of an FCC lattice? Give a set of basis vectors for the reciprocal space lattice.
- (c) Suppose x-rays with wavelength λ are scattered off a powder specimen of an FCC lattice. What are the angles of the first four diffraction rings in terms of λ and a ?

(d) Now suppose that one has a crystal in which atom A is located at the corners of the FCC cubes and atom B is located at the centers of the faces of the cubes. What is the underlying Bravais lattice for this crystal? Describe the positions of the atoms mathematically.

(e) How do the results of part (c) change (if at all) for this lattice?

3. Periodic potentials

A one dimensional crystal has alternating atoms A and B as shown in the figure below.



(a) Write down the Fourier transform of the Schrodinger equation for a periodic potential in one dimension.

(b) For the potential of the above one dimensional crystal what is the smallest non-zero wave number, K , for a non-zero U_K ?

(c) Solve for the energy in the vicinity of $K/2$.

(d) Sketch the energy as a function of wave vector in the first Brillouin zone.

(e) If all the atoms were the same, i.e. $A = B$, how would your results change. Sketch energy as a function of wave vector for this case as well as the part (d) case on the same graph.

4. Transport

(a) Write down the equations used in the Drude model for electrons in an electric field $\vec{E} = E\hat{x}$ and a magnetic field $\vec{B} = B\hat{y}$. Both the electric and magnetic fields are uniform and time independent.

(b) Solve for the electrical current in the x , y , and z directions.

(c) Write down the semiclassical equations of motion a magnetic field $\vec{B} = B\hat{y}$ with no scattering. The magnetic field is uniform and time independent.

- (d) What are two constants of the motion? *Prove* that they are constants of motion. Hint: They are the same constants as in the classical case.

- (e) A Fermi surface is drawn below in the repeated zone scheme. Sketch an open and a closed path solve it graphically. Draw your own x, y, and z coordinate axes on the figure.

