Physics 322 – 2007 Walter F. Smith
Exam 1 coverage

Coverage: Kittel Chapters 1 and 2 or equivalents
Livingston Chapter 7
Problem sets 1-5
Classes 1-12

Equation sheet: You will be allowed to create an equation sheet with up to 20 equations to refer to during the exam. No text or pictures allowed.

Critical Topics:

Crystal Structure Basics
- Lattice translation vectors and primitive vectors
- Lattice + Basis = crystal structure
- How symmetries distinguish Bravais lattice types
- **Miller indices: be ready calculate the Miller indices from a sketch of the plane (even for a non-cubic crystal), or vice versa**
- Memorize the following structures: fcc, bcc, diamond, hexagonal
- fcc and hcp are close-packed structures
- Primitive cell vs. conventional cell

Reciprocal lattice
- **Definition in terms of plane waves that match crystal periodicity**
- Definition in terms of the wavevectors that could be used for Fourier analysis of a function with periodicity of the lattice (e.g. the electron density)
- **How to find reciprocal lattice primitive vectors from direct lattice primitive vectors (both graphically and with the equations; i.e. be ready to do this if I just sketch the direct lattice for you, but also if I instead give you the primitive vectors of the direct lattice)**
- $\mathbf{G} \cdot \mathbf{T} = 2\pi$ (integer)
- Know that r.l. for bcc is fcc & vice-versa
- **Brillouin zones: definition, importance for Brillouin formulation of diffraction, fact that *k*-space volume of higher zones is the same as that of the 1BZ.**

X-ray diffraction
- Bragg & von Laue formulations
- **Brillouin construction**
- **Know the connections between the Bragg and the Brillouin/von Laue constructions, i.e. if given one, be ready to construct the other, including being able to make *k*-space drawings *to scale* showing the reciprocal lattice, k, k', and G. Here are the most important equations that illustrate the connections:**
  - $G = |\Delta\mathbf{k}| = \frac{2\pi n}{d}$**, G is perpendicular to the Bragg planes which are separated by *d***
  - **For diffraction off the family of planes (*hkl*),** $G = |\Delta\mathbf{k}| = h\mathbf{b}_1 + k\mathbf{b}_2 + l\mathbf{b}_3$
- Powder diffraction

Math
- Complex exponential version of Fourier analysis
- Expression for plane waves propagating in an arbitrary direction

Phonons

Dispersion relation
- Know it, be ready for problems relating to it.
- **Be able to explain why each wavevector outside the 1BZ is equivalent to one inside the 1BZ**
- **Know that these equivalent wavevectors differ by a reciprocal lattice vector**
- **Be ready to prove the above two things mathematically for a three-dimensional crystal**

Phase velocity and group velocity

Know meanings, definitions, and graphical representations (on the dispersion curve)

Phonon direction: understand the indexing system, e.g. [110]

Transverse and longitudinal phonons

Optical phonons

Know what they are, where the name comes from, and remember that the two parts of the basis need not have opposite charge.

Phonon energy

Know and understand $\varepsilon = \left(n + \frac{1}{2}\right)\hbar\omega$

Know how the phonon occupancy relates to the amplitude of vibration

Einstein and classical models for the phonon heat capacity