**Physics 322-2007 Solid State Physics Walter F. Smith Haverford College**

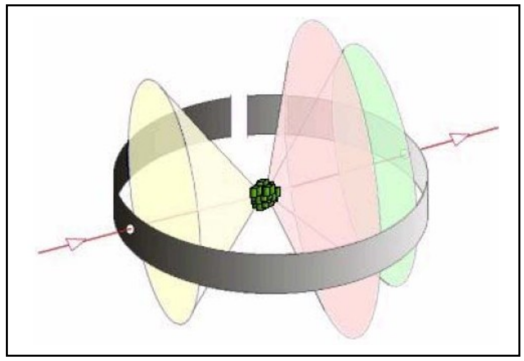
**Assignment 4**
**Due:** Friday, Sept. 28 at 4 pm (Turn in to envelope outside my office.)
**Reading**: Livingston Ch. 1, 12.1, 12.2

**Assigned exercises (except as noted, these are group problems, i.e. you may work on them with other students in small groups)**

**4A. (individual problem)** For a two-dimensional square lattice, show graphically that the several pieces of the fourth Brillouin zone have an area equal to that of the first zone. The easiest way to do this is to imagine translating the pieces of the fourth zone into the first zone, so as to fill it up. Use graph paper to make an accurate drawing, and use coloring or shading to indicate the initial and final positions of the various pieces.

**4B.** Sketch the Brillouin representation for the diffraction event described in problem 2A part a.

**4C.** For an fcc lattice, find the values of sin $\theta$ corresponding to the first four rings of the powder diffraction pattern. Express your answers in terms of the ratio $\lambda / a$, where $a$ is the sidelength of the conventional unit cell. *Hint: One way to approach this problem is to start with the primitive vectors of the reciprocal lattice. By using the primitive vectors for your calculations, rather than the vectors defining the conventional cell of the reciprocal lattice, you avoid the need to think about the "missing diffraction events" that we discussed in class. Eventually, you will use* $G = \frac{2\pi n}{d}$ .



**4D.** A beam of 150-eV electrons passes through a microcrystalline thin film of nickel (equivalent to a powder sample). Find the two smallest values of $2\theta$ for which diffraction occurs. Ni has an fcc lattice with a cube edge equal to 3.25 Å.

**4E.** Although we have extensively discussed the indexing system for the planes of a crystal, we have not talked much about the system for different vector directions in a crystal; this is discussed on Kittel p. 13 (p. 14 in 7th ed.). **For a crystal with cubic symmetry**, such as an fcc crystal, the [111] direction is perpendicular to the set of (111) planes, and the [100] direction is perpendicular to the set of (100) planes.
**a)** In terms of the sidelength a of the conventional unit cell, what is the minimum wavelength for a vibrational wave traveling in the [100] direction in an fcc structure?
**b)** What is the minimum wavelength for a vibrational wave travelling in the [111] direction for this system?

**Assignment continues on the next page**

**4F.** (Adapted from Kittel problem 4.6) **Atomic vibrations in a metal.** Consider point ions of mass $M$ and positive charge $e$ immersed in a uniform sea of conduction electrons. If one ion is displaced a small distance $r$ from its equilibrium position, the restoring force is largely due to the negative charge left behind in the sphere of radius $r$ centered at the equilibrium position.

**a.** Find the angular frequency of vibration for a single ion displaced from equilibrium in terms of the electron density $n$. (The electron density is the number of conduction electrons per unit volume.)

**b.** Estimate the numerical value of this frequency for sodium, which has one conduction electron per atom. (I expect you to find the necessary physical data on your own. There are tables in Kittel, but this is also easily available on the web. Be sure to cite your sources.)

**c.** Assume that the angular frequency you found in part a is associated with the maximum phonon wavevector. (Since it characterizes the vibration of one atom with its neighbors at equilibrium, this is very similar locally to the alternating up-down pattern of the maximum phonon wavevector.) Using your answer to part b, **estimate** the speed of sound (phase velocity) in sodium.