NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 580 – Solid State Physics Fall 2022

Problem Set #3

Problem Set Due: Tues (for Vesta) & Thurs., Sept. 15, 2022
Read Kittel: Chapter 2, powerpoints: *Geometry of Crystals* & *Miller Indices*

1. Download Vesta (https://jp-minerals.org/vesta/en/) and make a model of the unit cell for Po (sc), Fe (bcc), and Cu (fcc) shown in slide 34 of the "Geometry of Crystals" powerpoint slide (the powerpoints are on Blackboard in the "Content" section). Bring you laptop to class on Tues to show your work on the overhead projector.

2. On slide 29 of the "Geometry of Crystals" is shows that there can be no face-centered tetragonal lattice. Explain why.

3. On slide 17 of the "Miller Indices": show why the $\left(\frac{1}{2}, \frac{1}{2}, \frac{1}{2}\right)$ atom of bcc does not lie on the (112) plane.

4. What is a family of planes? What are the members of the family of planes for the (112) plane of a cubic crystal?

5. Give the miller indices of all six sides of the simple cubic crystal (note, some of these planes pass through the origin).

6. What is the distance between (100) planes for a cubic crystal? What is the distance between (200) planes for a cubic crystal?

7. Kittel: **Problem 4** page 44

4. ***Width of diffraction maximum.*** We suppose that in a linear crystal there are identical point scattering centers at every lattice point $\boldsymbol{\rho}_m = m\mathbf{a}$, where m is an integer. By analogy with (20), the total scattered radiation amplitude will be proportional to $F = \Sigma \exp[-im\mathbf{a} \cdot \Delta\mathbf{k}]$. The sum over M lattice points is

$$F = \frac{1 - \exp[-iM(\mathbf{a} \cdot \Delta\mathbf{k}]}{1 - \exp[-i(\mathbf{a} \cdot \Delta\mathbf{k})]} \ ,$$

by the use of the series

$$\sum_{m=0}^{M-1} x^m = \frac{1 - x^M}{1 - x} \ .$$

(a) The scattered intensity is proportional to $|F|^2$. Show that

$$|F|^2 \equiv F^*F = \frac{\sin^2 \frac{1}{2} M(\mathbf{a} \cdot \Delta\mathbf{k})}{\sin^2 \frac{1}{2} (\mathbf{a} \cdot \Delta\mathbf{k})} \ .$$

(b) We know that a diffraction maximum appears when $\mathbf{a} \cdot \Delta\mathbf{k} = 2\pi h$, where h is an integer. We change $\Delta\mathbf{k}$ slightly and define ϵ in $\mathbf{a} \cdot \Delta\mathbf{k} = 2\pi h + \epsilon$ such that ϵ gives the position of the first zero in $\sin \frac{1}{2} M(\mathbf{a} \cdot \Delta\mathbf{k})$. Show that $\epsilon = 2\pi/M$, so that the width of the diffraction maximum is proportional to $1/M$ and can be extremely narrow for macroscopic values of M. The same result holds true for a three-dimensional crystal.