THE UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF PHYSICS

MID-TERM EXAMINATION

21. April 2016

PHYS3080 Solid State Physics

PHYS3021 Statistical and Solid State Physics

PHYS9783: Advanced Solid State Physics 1

1. Time Allowed: 1 hour
2. Total number of questions: 4
3. Marks available for each question are shown in the examination paper. The total number of marks is 40.
4. Attempt ALL questions!
5. University-approved calculators may be used.
6. Answers must be written in ink. Except where they are expressly required, pencils may only be used for drawing, sketching or graphical work. Do not use red ink.
7. The exam paper may be retained by the candidate.

Question 1 (10 marks)

Filling factor and density of gold.

(for all questions: show your working)

Gold (Au, atomic mass: $196.97u = 3.30 \cdot 10^{-25}$ kg) crystalizes in the **fcc** (face centered cubic) structure and has a lattice parameter of $a = 4.07$ Å.

(a) Calculate the nearest-neighbor and second nearest-neighbor atomic distances and give the number of the corresponding neighbors, i.e. their coordination number.

(b) Calculate the atomic filling factor, i.e. under the assumption of fixed hard spheres, which are just touching each other.

$$F = \frac{\text{Volume of all spheres}}{\text{Volume of the Unit Cell}}$$

(c) Determine the maximum radius of the 'empty sphere' which would be located in the center of the cube.

(d) Calculate the density of gold.

Question 2 (10 marks)

Explain the following, each in a few words

(a) Give the five different chemical bonds inside a solid and sort them by their strength (strongest to weakest).

(b) What are static and dynamic lattice defects? Give one example for each!

(c) Symmetry operations: give the different rotational axis and give a brief explanation why other axis do not exist.

(d) Derive the expression for Bragg's law and plot a figure which explains this expression.

(e) Sketch the setup of a 'X-ray Powder Diffraction Experiment' and label the different items properly. Is the incident beam monochromatic or polychromatic?

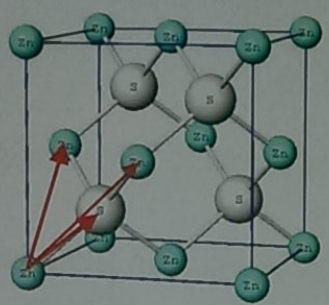
Question 3 (10 marks)

Reciprocal Lattice

(a) Give the expression for a reciprocal lattice vector.

(b) Give the three real space vectors of the atomic positions of the ZnS lattice (bi-atomic Diamond structure), as denoted in the figure.

(c) Calculate the three reciprocal lattice vectors using the three real space lattice vectors.



Question 4 (10 marks)

Sound Velocity

The equations of atomic motion for sound waves in a cubic solid are give by:

$$\varrho\frac{\partial^2 u}{\partial t^2} = c_{11}\frac{\partial^2 u}{\partial x^2} + c_{44}\left(\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) + (c_{12}+c_{44})\left(\frac{\partial^2 v}{\partial x \partial y} + \frac{\partial^2 w}{\partial x \partial z}\right)$$

$$\varrho\frac{\partial^2 v}{\partial t^2} = c_{11}\frac{\partial^2 v}{\partial y^2} + c_{44}\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial z^2}\right) + (c_{12}+c_{44})\left(\frac{\partial^2 u}{\partial x \partial y} + \frac{\partial^2 w}{\partial y \partial z}\right)$$

$$\varrho\frac{\partial^2 w}{\partial t^2} = c_{11}\frac{\partial^2 w}{\partial z^2} + c_{44}\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right) + (c_{12}+c_{44})\left(\frac{\partial^2 u}{\partial x \partial z} + \frac{\partial^2 v}{\partial y \partial z}\right)$$

(a) How can you measure the sound velocity in a single crystal. Give a sketch of the experimental setup and explain the experiment.

(b) How many acoustic modes exist in a three dimensional crystal?

(c) The wave functions for the atomic displacements for a wave travelling in [110]-direction are given by:

$u = u_0 \exp[i(k_x x + k_y y - \omega t)]$, $v = v_0 \exp[i(k_x x + k_y y - \omega t)]$,
and $w = w_0 \exp[i(k_x x + k_y y - \omega t)]$

Solve the equations of motion and calculate the corresponding sound velocities. (show your working).

(Hint: one of the three requested solutions is:

$\omega^2 \varrho = c_{44} k^2$, $v_{\text{gr.}} = \sqrt{c_{44}/\varrho}$; where $k^2 = k_x^2 + k_y^2$).