Question 1 (10 marks)

Bragg's Law

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

(b) Powder Diffraction experiment:

The incident wavelength of the neutron beam is $\lambda = 2.662$ Å. The material possesses a simple cubic crystal structure with a lattice parameter of 3.26 Å. Calculate the scattering angle of the following Bragg peaks:

[100], [200], [110], and [111].

Question 2 (10 marks)

Explain the following, each in a few words

(a) Give the five different chemical bonds inside a solid sorted them by their strength.

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

(c) Describe three different symmetry operations and give their proper symbol using either the Schönfliess or Hermann-Mauguin notation.

(d) Give the different rotational axis and give a brief explanation why other axis do not exist.

(e) Explain the Piezoelectric effect. Do crystals with a center of inversion show piezoelectric properties? Use a sketch to answer this question.

Question 3 (10 marks)

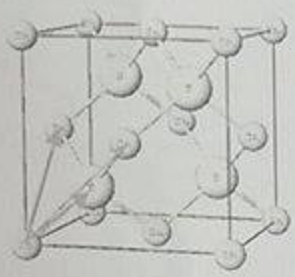
Reciprocal Lattice

(a) Give the expression of the reciprocal lattice vectors.

(b) Calculate for the three-dimensional volume in real and reciprocal space the following: $\vec{R}_n \cdot \vec{G}_h = ...$

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

(d) Calculate the reciprocal lattice vector using these three lattice vectors.



Question 4 (10 marks)

Lattice vibrations

(a) Ho 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 and optical phonon modes exist in a three dimensional bi-atomic crystal?

(c) Sketch the phonon dispersion relation of a three dimensional bi-atomic crystal and label the acoustic and optical phonon branches.

(d) The dispersion relation of a one-dimensional bi-atomic linear chain is given by:

$$\omega^2 = \gamma\left(\frac{1}{M_1}+\frac{1}{M_2}\right) \pm \sqrt{\left(\frac{1}{M_1}+\frac{1}{M_2}\right)^2 - \frac{4sin^2(ka/2)}{M_1 M_2}}^{1/2}$$

(i) Calculate the energy the optical phonon at the center of the Brillouin zone, $k = 0$.

(ii) Calculate the energies of the optical and acoustic phonon branches at the boundary of the Brillouin zone, $k = \pm\pi/a$.

(iii) Calculate the sound velocity i.e. the slope of the acoustic phonon branch at $k \sim 0$.