1. Calculate the isothermal bulk modulus for a NaCl crystal using given in the lecture expression for the lattice energy:

\[ U(R) = N \left( z \lambda e^{-R/\rho} - \alpha \frac{q^2 e^2}{4\pi\epsilon_0 R} \right) . \]

Hint: The (isothermal) bulk modulus is given by \( K = V \frac{d^2 U}{dV^2} |_{R_0} \), i.e. it requires the relation between volume \( V \) and distance \( R \), as well as the equilibrium distance \( R_0 \).

2. Determine the binding energies of KCl with NaCl structure and zinc-blende structure. The potential parameters are \( z \lambda = 2.05 \times 10^{-15} \) J and \( \rho = 0.326 \) Å.

3. The wave functions \( \psi_{nlm} \) for the 2s and 2p states are in spherical coordinates \((r, \theta, \phi)\):

\[
\psi_{200} = c(1 - \rho)e^{-\rho} ;
\]

\[
\psi_{210} = i c \rho e^{-\rho} \cos \theta ;
\]

\[
\psi_{211} = -i \frac{c}{\sqrt{2}} \rho e^{-\rho} \sin \theta e^{i\phi} ;
\]

\[
\psi_{21\bar{1}} = i \frac{c}{\sqrt{2}} \rho e^{-\rho} \sin \theta e^{-i\phi} .
\]

Here \( \rho = r/(2a_B) \) with the Bohr radius \( a_B \) and \( c = 2/\sqrt{4\pi(2a_B)^3} \).

Discuss the angular dependence of the wave functions

\[
\psi_{p_x} = \frac{i}{\sqrt{2}} (\psi_{211} - \psi_{21\bar{1}}) , \psi_{p_y} = \frac{1}{\sqrt{2}} (\psi_{211} + \psi_{21\bar{1}}) , \psi_{p_z} = -i\psi_{210} .
\]

Are these functions orthonormal to each other? (You can assume that the wave functions \( \psi_{nlm} \) are orthonormal.)