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UNIVERSITY OF CAPE COAST
COLLEGE OF EDUCATION STUDIES
SCHOOL OF EDUCATIONAL DEVELOPMENT AND OUTREACH
INSTITUTE OF EDUCATION

FIVE-SEMESTER BACHELOR OF EDUCATION (SANDWICH) PROGRAMME
SECOND YEAR, END-OF-THIRD SEMESTER EXAMINATION, SEPTEMBER 2019

SEPTEMBER 5, 2019

SOLID STATE PHYSICS

2:00 PM – 4:00 PM

Answer <u>question 1</u> and any TWO others

1. a. What is Lattice?
   b. What is a phonon?
   c. The molecules of a solid are held in a number of ways. What are the two common ways that solid molecules are held?
   d. Discuss a linear lattice with two types of the in alternating position. Consider only the harmonic approximation with nearest neighbor interactions.
   e. Explain why lattice vibrations scatter electrons.

(40 Marks)

2. a. Describe ways in which energy band containing electrons in a good insulator are filled.
   b. How many conduction electrons are in a cube of magnesium with a volume of 2.00×10^{-6} m^3. Magnesium atoms are bivalent (Magnesium has density of 1.738×10^3 kg/m^3 and a molar mass M OF 24.312×10^{-3} kg/mol) Hint : number of conduction electrons in sample = number of atoms in sample x number of valence electrons per atom. (30 Marks)

3. a. If the many – particle Schrodinger wave equation is

$$\mathcal{H}_c\psi = i\hbar\frac{\partial\psi}{\partial\psi}$$ where $\mathcal{H}_c$ is the crystal Hamiltonian. State the Hamiltonian $\mathcal{H}_c$ of the crystal.

   b. Given that the volume coefficient of thermal expansion $\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$, the isothermal compressibility $K = \frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$ and $\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial P}{\partial V}\right)_T\left(\frac{\partial T}{\partial P}\right)_V = -1$ and where F is free energy. Show that $P = -\frac{\partial}{\partial V}\left[U_0 + \sum_{k.j}\frac{1}{2}\hbar\omega_j(k)\right] + \sum_{k.j}\bar{n}_j(k)\frac{\hbar\omega_j(k\gamma)}{V}$. (30 Marks)

4. Let a be the separation of two atoms 1 and 2 . x_1 and x_2 are the coordinates measuring the displacement of atoms 1 and 2 from equilibrium and m is the mass of atom 1 or 2 . With periodic boundary conditions, Newton's second law for each of the two atoms is

$$m\ddot{x}_1 = \gamma(x_2 - x_1) - \gamma(x_1 - x_2)$$

$$m\ddot{x}_2 = \gamma(x_1 - x_2) - \gamma(x_2 - x_1)$$

where each dot means a derivative with respect to time. Show that the quantum –mechanical energies of the fixed two-atom crystal are given by

$E_n = \left(n + \frac{1}{2}\right) h \sqrt{\frac{4\gamma}{m}}$ where γ is the spring constant of the springs coupling the atoms (Hint : the normal mole solution is given as $x_n U_n e^{i\omega t}$). (30 Marks)

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