TECHNICAL UNIVERSITY OF MOMBASA

FACULTY OF APPLIED &HEALTH SCIENCES

MATHEMATICS & PHYSICS DEPARTMENT

UNIVERSITY EXAMINATION FOR:

BACHELOR OF TECHNOLOGY IN APPLIED PHYSICS AND BACHELOR OF TECHNOLOGY IN ENVIRONMENTAL PHYSICS & RENEWABLE ENERGY

APS 4306: SOLID STATE PHYSICS

END OF SEMESTER EXAMINATION

SERIES: MAY 2016

TIME: 2 HOURS

DATE: MAY 2016

Instructions to Candidates

You should have the following for this examination

-Answer Booklet, examination pass and student ID

This paper consists of 4 questions.

Do not write on the question paper. Answer question ONE (compulsory) and any other two questions.

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SECTION A (30MARKS)

QUESTION 1

(a) Explain the following terms:

(i)Basis [2points]

(ii)A Wigner-Seitz cell [3points]

(b) (i) How many lattice points are there per primitive cell? Explain your answer. [3points]

(ii) Explain how you would compute the Miller indices of a crystal plane. [3points]

(c) (i) Derive the Bragg law of diffraction. [5points]

(ii) Using Fourier analysis and translational invariance of crystal show that,

n(**r**+**T**) = n(**r**), where **T** = $u_1\mathbf{a}_1 + u_2\mathbf{a}_2 + u_3\mathbf{a}_3$ [4points]

(d) (i) Consider nearest neighbor planes, s and s ± 1. The force on the s plane due to the two the two other planes is given by,

$F_s = C(u_{s+1} - u_s) + C(u_{s-1} - u_s)$ where the letters have their usual meanings.

write down the equation of motion of an atom in the plane s, solve it and show that

the frequency of motion is given by $\omega^2 = \frac{4C}{M}\sin^2\frac{1}{2}Ka$ [7points]

(ii) Sketch the graph of the frequency versus the wave vector K. [3points]

QUESTION 2 (20Points)

(a) Explain the following terms,

(i) Brillouin zone [3Points]

(ii) Structure factor and atomic form factor [3points]

(b) (i) Give the expression for the energy of a collection of oscillators of frequency

$\omega_{K,p}$ [3points]

(ii)Using the expression you gave in (i) above, determine the expression

for the lattice heat capacity. [4points]

(c) Discuss the Debye model for density of states and show that in this model

the heat capacity is given by $C_V = \frac{3V\hbar^2}{2\pi^2 v^3 k_B T^2}\int_0^{\omega_D} d\omega \frac{\omega^4 e^{\hbar\omega/\tau}}{\left(e^{\hbar\omega/\tau} - 1\right)^2}$.

Do not perform the integration. Just leave the expression in its integral form. [7Points]

QUESTION 3

(a) Explain what is meant by cohesive energy in crystal binding. [3Points]

(b) Discuss the Einstein model for the density of and determine the expression for heat capacity in this model. [7Points]

(c) The cohesive energy of an inert gas is given by

$$U_{total} = \frac{1}{2} N(4\varepsilon)\left[\sum_{ij}\left(\frac{\sigma}{p_{ij}R}\right)^{12} - \sum_{ij}\left(\frac{\sigma}{p_{ij}R}\right)^{6}\right]$$

For $R = R_{0,}$ and $\sum_j p_{ij}{}^{-12} = 12.131188$, $\sum_j p_{ij}{}^{-6} = 14.45392$ compute the total energy at $R = R_0$. The letters in all the expressions have their usual meanings. [10Points]

QUESTION 4

(a) Write down the free-particle Schrodinger equation in three dimensions. [3points]

(b) Solve this problem and determine the energy of the orbital wave vector k. [4Points]

(c) From the solution above continue and determine expression for the Fermi energy and hence, density of states and heat capacity of an electron gas. [13Points]