



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.

SECTION A (30 MARKS)

QUESTION 1

(a) Explain the following terms:

(i) Basis [2 points]

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

(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,

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

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

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

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

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

(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

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

(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

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

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]

