JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

UNIVERSITY EXAMINATION FOR THE DEGREE OF BARCHELOR IN EDUCATION SCIENCE WITH IT

MAIN

REGULAR

COURSE CODE: SPB 9322

COURSE TITLE: INTRODUCTION TO SOLID STATE PHYSICS

EXAM VENUE: **STREAM: BACHELOR OF EDUCATION**

DATE: **EXAM SESSION:**

TIME: 2:00HRS

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1. **Instructions: Answer question 1 (Compulsory) in Section A and ANY other 2 questions in Section B.**
2. **Candidates are advised not to write on the question paper.**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room.**

QUESTION 1 (30 MARKS)

a. Define the following terminologies

I. Basis [2mks]

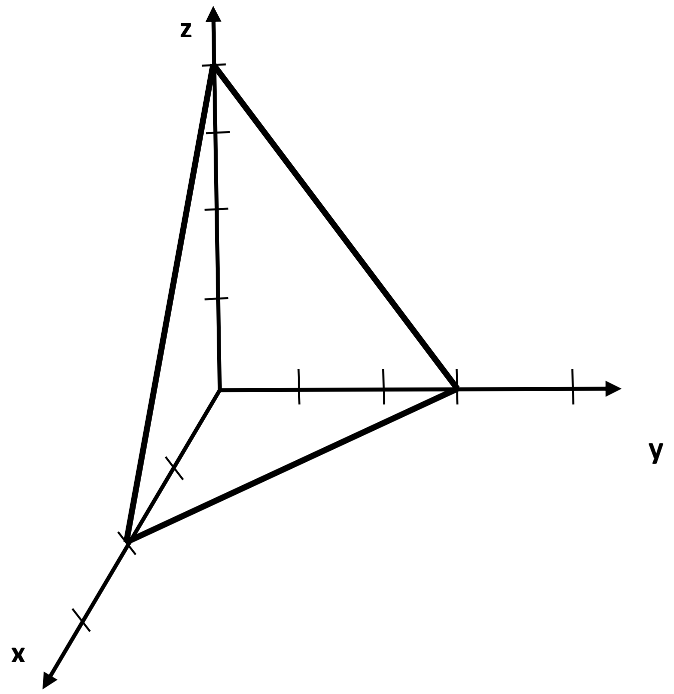
II. Bravais Lattice [2mks]

III. Wigner Seitz Cell [2mks]

b) Compare the specific heat per mole of a monoatomic and a diatomic gas at constant volume. Use appropriate equations to explain your answer. [4mks]

c) The Debye temperature θ for iron is known to be 360 K. Calculate v_m, the maximum frequency [4 mks]

d) Find the Miller indices of the plane below [4 mks]



e) Define the Debye Temperature T_D in terms of the Debye frequency ω_D [2mks]

f) The Debye temperature θ for iron is known to be 360 K. Calculate v_m, the maximum frequency [4mks]

g) State the Dulong-Petit Law for crystalline matter [2mks]

h) An FCC unit cell contains 4 atoms, show that the Parking Ratio (PR) is given by 0.74

[4mks]

QUESTION 2 (20MARKS)

a) Use the **Band theory,** explain the construction of band gap [5 mks]

b) Explain the following phenomena

i. The energy of a neutron is so much smaller than that of an electron in radiation beams but it is employed in crystal diffraction [2 mks]

ii. Light beam cannot be used in the analysis of crystal structure [2 mks]

iii. Neutrons are more useful than the proton in structure analysis [2 mks]

c) The edge of a unit cell in a simple cubic crystal is a = 2.62 X 10^{-10}m. Given that the monochromatic X-ray has a wavelength of 1.54 Amstrongs, find the Bragg angle corresponding to reflection from the plane (211) [3 mks]

d) The Bragg angle for reflection from the (110)-planes in BCC iron is 22^{o} for an X-ray wavelength of 1.54 Amstrongs

i. Calculate the cube length [3 mks]

ii. What is the Bragg angle for reflection from the (121)-planes? [3 mks]

QUESTION 3 (20MARKS)

a) The energy of interaction of two atoms a distance *r* apart can be written as:

$E(r) = -\frac{p}{r} + \frac{q}{r^7}$ where *p* and *q* are constants.

i. Show that for the particles to be in equilibrium, $r = r_o = (7\, q/p)^{1/6}$ [4mks]

ii. In stable equilibrium, show that the energy of attraction is seven times that of the repulsion [4mks]

iii. The energy of attraction and repulsion at a stable equilibrium are equal. Show [3mks]

b)

i) Define mobility of a carrier of current and show how it is related to the **Hall Coefficient** [3mks]

ii) Compare the mobility of an electron in the conduction band of a semiconductor and the mobility of an electron (or hole) in the valence band. Give reason for your answer [3mks]

iii) Derive an expression for the electrical conductivity of a metal on the basis of free electron [3mks]

QUESTION 4 (20 MARKS)

a) Define Brillouin zone [2 mks]

b) Consider a plane $h \quad k \quad l$ in a crystal lattice which intersects the crystal axis as $x_1\vec{a}, x_2\vec{a}_2, x_3\vec{a}_3$

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i. Prove that the reciprocal lattice vector $\vec{G} = h\vec{b}_1 + k\vec{b}_2 + l\vec{b}_3$ is perpendicular to this plane. [6 mks]

ii. Prove that the distance between the two adjacent parallel planes of the lattice is $d(hkl) = \dfrac{2\pi}{|\vec{G}|}$ [6 mks]

iii. Show for a simple cubic lattice that $d = \dfrac{a}{\sqrt{h^2 + k^2 + l^2}}$ [6 mks]

QUESTION 5 (20 MARKS)

a. Compare the specific heat per mole of a monoatomic and a diatomic gas at constant volume. Use appropriate equations to explain your answer. [5mks]

b. Calculate the specific heat capacity of a monoatomic crystalline solid [6mks]

c. Debye's model of solids gives the expression for specific heat $C_v = 9N_0k\dfrac{1}{x^3}\int_0^x \dfrac{\sigma^4 e^\sigma}{(e^\sigma - 1)^2} dE$

where $\sigma = \dfrac{h\upsilon}{kT}$, $x = \dfrac{h\upsilon_m}{kT}$ and $\theta_D = \dfrac{h\upsilon_m}{k}$ is the Debye's characteristic temperature. Show that;

i. At high temperatures, Debye's model gives Dulong Petit law [6mks]

ii. At low temperatures it gives $C_v \propto T^3$ in agreement with the experiment [3mks]