NATIONAL OPEN UNIVERSITY OF NIGERIA
PLOT 91, CADASTRAL ZONE, NNAMDI AZIKIWE EXPRESSWAY, JABI - ABUJA
FACULTY OF SCIENCES
DEPARTMENT OF PHYSICS

2025_1 EXAMINATION

COURSE CODE: PHY 307
COURSE TITLE: SOLID STATE PHYSICS I
CREDIT UNIT: 2
TIME ALLOWED: (2 HRS)
INSTRUCTION: ***Answer question 1 and any other two questions***

QUESTION 1

(a). Define Crystal (2 marks)

(b). State the three conditions that must be met before Cauchy relations can be valid. (6 marks)

(c). Discuss the Free electron model (3 marks)

(d). Prove that the reciprocal lattice vectors as defined in: $A = 2\pi \frac{b \times c}{a.b \times c}$ $B = 2\pi \frac{c \times a}{a.b \times c}$ $C = 2\pi \frac{a \times b}{a.b \times c}$, satisfy $A.B \times C = \frac{8\pi^3}{a.b \times c}$ (10 marks)

(e). Assuming that the conduction electrons in a cube of a metal on edge 1 cm behave as a free quantized gas, calculate the number of states that are available in the energy interval 4.00–4.01 eV, per unit volume. (9 marks)

QUESTION 2

(a). Define the following terms: (i) Lattice (ii) Unit cells (4 marks)

(b). Differentiate between primitive and non-primitive cells (2 marks)

(c). The real space primitive lattice vectors are $\vec{a}_1 = a\hat{x}$, and $\vec{a}_2 = \frac{a}{2}(\hat{x} + \sqrt{3}\hat{y})$. Show that the reciprocal space unit vectors b_1 and b_2 for this lattice are, respectively $\frac{2\pi}{a}(\hat{x} - \frac{\hat{y}}{\sqrt{3}})$ and $\frac{4\pi}{a\sqrt{3}}\hat{y}$, respectively. (8 marks)

(d). An x-ray beam of wavelength 0.16 nm is incident on a set of planes of a certain crystal. The first Bragg reflection is observed for an incidence angle of 36°. What is the plane separation? Will there be any higher order reflections? (6 marks)

QUESTION 3

(a). Write short notes on the following: (i) ionic bonding (ii) Covalent bonding (iii) Metallic bonding. (6 marks)

(b). Show that the velocity of a longitudinal wave in the [111] direction of a cubic crystal is given by

$$v_s = [\frac{1}{3}(C_{11} + C_{12} + 4C_{44})]^{1/2}$$

(9 marks)

(c). In a cubic unit cell, find the angle between normals to the planes (111) and (121).

(5 marks)

QUESTION 4

(a). State four assumptions of Drude model (4 marks)

(b). Discuss briefly the concept of Fermi surfaces (2 marks)

(c). For a free electron gas in a metal, the number of states per unit volume with energies from E to $E + dE$ is given by $n(E)dE = \frac{2\pi}{h^3}(2m)^{3/2} E^{1/2} dE$ Show that the total energy = $3NE_{\text{max}}/5$. (8 marks)

(d). Calculate the Fermi energy for silver given that the number of conduction electrons per unit volume is 5.86×10^{28} m^{-3}. (6 marks)

QUESTION 5

(a). Define the transition temperature in superconductivity (2 marks)

(b). Define the critical magnetic field and current of a superconductor (4 marks)

(c). After adding an impurity atom that donates an extra electron to the conduction band of silicon ($\mu_n = 0.13$m^2/Vs), the conductivity of the doped silicon is measured as 1.08 (Ωm^{-1}). Determine the doped ratio (density of silicon is 2420 kg/m3). (8 marks)

(d). Show that at the room temperature (300 K) the electron densities in the conduction bands of the insulator carbon (Eg = 5.33 eV) and the semiconductor like germanium (Eg = 0.7 eV) is extremely small. (Where Boltzmann' constant is 1.38×10^{-23}; electronic charge: 1.6×10^{-19})

(6 marks)