NATIONAL OPEN UNIVERSITY OF NIGERIA
PLOT 91, CADASTRAL ZONE, NNAMDI AZIKIWE EXPRESSWAY, JABI - ABUJA
FACULTY OF SCIENCES
DEPARTMENT OF PHYSICS
2025_2 EXAMINATIONS

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 the term Crystal binding (2 marks)

(b). What are Miller indices? (2 marks)

(c). State the rules for determining Miller indices (4 marks)

(d). Let the interaction energy between two atoms be given by: $E(r) = -\frac{A}{r^2} + \frac{B}{r^8}$ If the atoms form a stable molecule with an inter-nuclear distance of 0.4 nm and a dissociation energy of 3 eV, calculate A and B. (10 marks)

(e). For an orbital of number N electrons in a sphere of radius k_F, and if there are two available spin states for a given set of k_x, k_y, and k_z, show that the relationship between N and k_F and the density of states are $k_F = (\frac{3\pi^2 N}{V})^{1/3}$ and $D(E) = \frac{3N}{2E}$, respectively. (12 marks)

QUESTION 2

(a). Write short note on the following terms: (i) Simple cubic lattice (ii) Body-Centered cubic Lattice (iii) Face- Centered Cubic Lattice (6 marks)

(b). If the x-, y-, and z-, are intercepts are 2, 1, and 3, calculate the Miller indices (6 marks)

(c). Show that $\sqrt{3}\pi/8$ of the available volume is occupied by hard sphere in contact in a body centered cubic arrangement. (8 marks)

QUESTION 3

(a). Define Lattice vibration (2 marks)

(b). What is harmonic approximation? and state the condition the must be met before it can hold. (3 marks)

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

$E(r) = \frac{a}{r} + \frac{b}{r^7}$, where a and b are constants. Show that for the particles to be in equilibrium, $r = r_0 = (\frac{7b}{a})^{1/6}$ (6marks)

(d). The force of attraction between ions of Na and Cl is 3.02 x 10^{-9} N when the two ions just touch each other. Given: ionic radius of Na^+ ion is 0.95 Å, e = 1.6 x 10^{-19} C, ε_0 = 8.854 x 10^{-12} C2 /N – m^2 . Find the radius of Cl^- ion. (9 marks)

QUESTION 4

(a). Define Energy band (1 marks)

(b). Explain the following in terms of energy bands : (i) Insulators (ii)Semiconductors (6 marks)

(c). Solid Ar has an fcc structure with cubic lattice constant a = 5.26 Å, atomic mass M_{AR} = 6.67 x 10^{-26} N/$m^2$and a Debye temperature θ_D = 92^0 K. Estimate the phonon velocity using the Young modulus of C_{11} = 1.6 x 10^{-9} N/m^2 . (6 marks)

(d). Einstein's model of solids gives the expression for the specific heat

$$C_v = 3N_0K\left(\frac{\theta_E}{T}\right)^2 \frac{e^{\theta_E/T}}{(e^{\theta_E/T} - 1)^2}$$

where $\theta_E = hv/k$. The factor θE is called the characteristic temperature. Show that (a) at high temperatures Dulong Petit law is reproduced. (b) But at very low temperatures the T^3 law is not given. (7 marks)

QUESTION 5

(a). Discuss Meissner effect in solids (4 marks)

(b). State Pauli principle (2 marks)

(c). At room temperature, $\frac{K_BT}{e} = 26\ mV$. A sample of cadmium sulfide displays a mobile carrier density of 10^{16} cm^{-3} and a mobility coefficient $\mu = 10^2 cm^2/volt\ sec$

(i) Calculate the electrical conductivity of this sample.

(ii) If the charge carriers have an effective mass equal to 0.1 times the mass of a free electron, what is the average time between successive scatterings. (6 marks)

(d). If N_d and N_a are the donor and acceptor impurity density of an extrinsic semiconducting material, show that the density of hole h and density of electron are related as in (all symbols represent usual meanings)

$n \approx (N_d - N_a)$ when $(N_d - N_a) \gg n_i$ and $p = (N_a - N_d)$ when $(N_a - N_d) \gg n_i$

(8 marks)