



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

DEPARTMENT OF PHYSICS

2024 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 three questions*

**QUESTION 1**

- (a). Define the following terms: (i) Barvais Lattice (ii) basis (4 marks)
- (b). Write Short note on the first Brillouin zone of a crystal plane? (4 marks)
- (c). 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. (7 marks)
- (d). Consider two-dimensional electrons subjected to a weak periodic potential coming from a square lattice of spacing  $a = 5\text{\AA}$ . For a k vectors far away from the Brillouin zone boundary, the wavefunction can be well described by planes waves. Assume we want to write the wavefunction in the Bloch form,  $\psi(k) = e^{-ikr}u(r)$ , and considering a state of energy E and wavevector  $k = \begin{pmatrix} 0.05\text{\AA}^{-1} \\ 0 \end{pmatrix}$ , show that the three lowest energies will be 0.95 eV, 2.17 and 6.96 eV, respectively at this wavenumber? (Note that  $\frac{\hbar^2}{m} = 3.806 \text{ eV\AA}^2$ ). (10 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 (5 marks)
- (b). The Bragg angle corresponding to the first order reflection from plane (111) in a crystal is  $30^\circ$  when X-rays of wavelength  $1.75 \text{\AA}$  are used. Calculate the interatomic spacing. (5 marks)
- (c). Show that the atomic radius r of a body centered cubic (BCC) can be determined as  $a^2 = \frac{16r^2}{3}$ , where a is the cubic edge element. (5 marks)

### QUESTION 3

- (a). State six characteristics of ionic solids (5 marks)
- (b). The ionic radii of  $Mg^{++}$  and  $S^-$  respectively are  $0.65 \text{ \AA}$  and  $1.84 \text{ \AA}$ . Calculate the force of attraction between these ions. Given:  $e = 1.6 \times 10^{-19} \text{ C}$ ,  $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$  (5 marks)
- (c). The energy vs. wave vector (E-K) relationship near the bottom of a band for a solid can be approximated as,  $E = A(ka)^2 + B(ka)^4$  where the lattice constant  $a = 2.1 \text{ \AA}$ . At the bottom of the conduction band, show that the effective mass of the electron is

$$m^* = \frac{\hbar}{2Aa^2}$$

(5 marks)

### QUESTION 4

- (a). State four assumptions of Drude model (4 marks)
- (b). In a Hall effect experiment, show that the hall voltage for an intrinsic semiconductor is negative. (4 marks)
- (c). The Fermi energies of two metals X and Y are 5 eV and 7eV and their Debye temperatures are 170 K and 340 K, respectively. The molar specific heats of these metals at constant volume at low temperatures can be written as  $(C_v)_X = \gamma_X T + A_X T^3$  and  $(C_v)_Y = \gamma_Y T + A_Y T^3$  where  $\gamma$  and A are constants. Assuming that the thermal effective mass of the electrons in the two metals are same, find the values of  $\frac{\gamma_X}{\gamma_Y}$  and  $\frac{T_X}{T_Y}$ . (7 marks)

### QUESTION 5

- (a) State five principal irregularities in the appearance of superconductivity. (4 marks)
- (b). Derive the London equation for super fluidity of current in a superconducting solid. (7 marks)
- (c). Suppose a solenoid constructed out of  $Nb_3Al$  which has  $B_{c2} = 32.0 \text{ T}$  at  $T=0\text{K}$  and critical temperature  $T_c = 18\text{K}$ . The wire has a radius of 1.0 mm and is wound on a hollow cylinder of diameter 8.0 cm and length 90.0 cm with 150 turns/cm. What is the maximum current the solenoid can carry if its temperature is maintained at  $T=15\text{K}$  and it remains superconducting. (4 marks)