MPH-012

ASSIGNMENT BOOKLET

M.Sc. (Physics) Programme
(MSCPH)

CONDENSED MATTER PHYSICS

Valid from 1st July, 2024 to 30th June, 2025

School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068
(2024-25)

Dear Student,

Please read the section on assignments in the Programme Guide for M.Sc. (Physics). A weightage of 30 per cent, as you are aware, has been earmarked for continuous evaluation, **which would consist of one tutor-marked assignment** for this course. The assignment is in this booklet. The total marks for this assignment is 100, of which 40 marks are needed to pass it.

Instructions for Formatting Your Assignments

Before attempting the assignment please read the following instructions carefully:

1) On top of the first page of your answer sheet, please write the details exactly in the following format:

ENROLMENT NO.: ……

NAME: ……

ADDRESS: ……

COURSE CODE:…….

COURSE TITLE: ……

ASSIGNMENT CODE: ……..

STUDY CENTRE: …….. **DATE:** …….

PLEASE FOLLOW THE ABOVE FORMAT STRICTLY TO FACILITATE EVALUATION AND TO AVOID DELAY.

2) Use only foolscap size writing paper (but not of very thin variety) for writing your answers.

3) Leave 4 cm margin on the left, top and bottom of your answer sheet.

4) Your answers should be precise.

5) **Submit the complete assignment answer sheets containing Part A and Part B, within the due date.**

6) The assignment answer sheets are to be submitted to your Study Centre as per the schedule. **Answer sheets received after the due date shall not be accepted. We strongly suggest that you retain a copy of your answer sheets.**

7) This assignment is **valid from 1st July 2024 to 30th June 2025**. If you have failed in this assignment or fail to submit it by June 30, 2025, then you need to get the assignment for the year 2025-26, and submit it as per the instructions given in the Programme Guide.

8) **You cannot fill the examination form for this course** until you have submitted this assignment. For any queries, please contact: mbnewmai@ignou.ac.in, slamba@ignou.ac.in

We wish you good luck.

Tutor Marked Assignment
CONDENSED MATTER PHYSICS

Course Code: MPH-012
Assignment Code: MPH-012/TMA/2024-25
Max. Marks: 100

Note: Attempt all questions. The marks for each question are indicated against it.

PART A

1. a) A metallic element has a density of 7.15 g cm^{-3}, a lattice constant of 2.880 Å and an atomic weight of 51.9961 . Calculate the number of atoms per unit cell of this element and predict its lattice crystal structure. (5)

   b) Show that the volume of the primitive cell in the reciprocal lattice space is inversely proportional to the volume of the primitive cell in the direct lattice. (5)

   c) At what angle will a diffracted beam emerge from the (110) planes of a cubic crystal of unit cell length 0.6 nm? Assume diffraction occurs in the first order and that the X-ray wavelength is 0.154 nm ? (5)

2. a) If the potential energy function is expressed as $U(r) = -\frac{\alpha}{r} + \frac{\beta}{r^8}$, calculate the inter-molecular distance at which the potential energy is a minimum. Show that in the stable configuration the energy of attraction is eight times the energy of repulsion. (10)

   b) Debye temperature for diamond is 2230 K. Calculate the frequency of highest possible lattice vibration in diamond and its molar heat capacity at 20 K. (5)

3. a) Metallic sodium is monovalent and crystallizes in a bcc structure with a lattice constant of 4.25 Å . Calculate the number density of conduction electrons and the Fermi energy at 0 K. (5)

   b) For a free electron gas in two dimensions, derive the relation between the number density of electrons and the Fermi wave vector. (5)

   c) For the energy dispersion relation:

$$\varepsilon(\vec{k}) = \frac{\hbar^2}{2}\left[\frac{k_x{}^2 + k_y{}^2}{m_1} + \frac{k_z{}^2}{m_2}\right]$$

   calculate the inverse mass tensor and the group velocity given $m_1 = 3m_2$. (5)

   d) Consider an electron in a bcc lattice with lattice constant b . Show that a wave function of the form:

$$\psi(x,y,z) = 1 + \cos\frac{2\pi}{b}(x+y) + \cos\frac{2\pi}{b}(y+z) + \cos\frac{2\pi}{b}(z+x)$$

   satisfies the Bloch theorem. (5)

PART B

4 a) Calculate the temperature at which the number of electrons in the conduction band of a semiconductor is four times the number at room temperature. Take the band gap energy to be 1.2 eV with $E_C - E_F \approx E_G$. (5)

b) Calculate the total voltage difference (the built-in potential) between the *n*-type and *p*-type part for a uniformly doped Silicon *p*-*n* junction with $N_d = N_a = 10^{23}$ m^{-3} at room temperature. The intrinsic carrier density is 1.45×10^{14} m^{-3}. Will the built-in voltage increase or decrease with an increase in temperature? (5)

5. a) What is the piezoelectric effect? Describe the piezoelectric effect in barium titanate. (5)

b) Derive the magnetization and susceptibility for the free spin (J=S=1/2). You may use the relation: $\coth(2x) = \dfrac{\coth^2 x + 1}{2\coth x}$. (10)

c) Describe the different types of exchange interactions that can give rise to spontaneous magnetic order. (5)

6. a) The critical field for Niobium (Nb) is 10^5 Am^{-1} at 8 K and 2×10^5 Am^{-1} at 0 K. Calculate the transition temperature . (5)

b) Calculate the super-electron density for Sn which has a London penetration depth of 34 nm. (5)

c) The transition temperature for an isotope of Mercury (Hg) with a mass of 199u is 4.185K. Calculate the transition temperature for an isotope of Hg with mass number 202u. Take the value of the exponent α to be 0.5. (5)

d) Calculate the wavelength of the photon required to break the Cooper pair in a superconductor with a transition temperature of 1.3 K. (5)

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