PHE-13

ASSIGNMENT BOOKLET
Bachelor's Degree Programme (B.Sc.)

PHYSICS OF SOLIDS

Valid from January 1, 2023 to December 31, 2023

It is compulsory to submit the Assignment before filling up the Term-End Examination Form.

Please Note

- You can take electives (56 or 64 credits) from a minimum of TWO and a maximum of FOUR science disciplines, viz. Physics, Chemistry, Life Sciences and Mathematics.
- You can opt for elective courses worth a MINIMUM OF 8 CREDITS and a MAXIMUM OF 48 CREDITS from any of these four disciplines.
- At least 25% of the total credits that you register for in the elective courses from Life Sciences, Chemistry and Physics disciplines must be from the laboratory courses. For example, if you opt for a total of 64 credits of electives in these 3 disciplines, at least 16 credits out of those 64 credits should be from lab courses.
- You cannot appear in the Term-End Examination of any course without registering for the course. Otherwise, your result will not be declared and the responsibility will be yours.

School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068

2023

Dear Student,

We hope you are familiar with the system of evaluation to be followed for the Bachelor's Degree Programme. At this stage you may probably like to re-read the section on assignments for Elective Courses in the Programme Guide that we sent you after your enrolment. A weightage of 30 per cent, as you are aware, has been earmarked for continuous evaluation which would consist of **one tutor-marked assignment (TMA)** for this course.

Instructions for Formatting Your Assignments

Before attempting the assignment please read the following instructions carefully.

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

ENROLMENT NO. : ……

NAME : ……

ADDRESS : ……

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COURSE CODE : ……..

COURSE TITLE : ……..…….

ASSIGNMENT NO. : ……..…

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 and in your own words. Do not copy answers from study material.

5) While solving problems, clearly indicate the question number along with the part being solved. Write units at each step of your calculations as done in the text because marks will be deducted for such mistakes. Take care of significant digits in your work. Recheck your work before submitting it.

6) **This assignment will remain valid from January 1, 2023 to December 31, 2023**. However, you are advised to submit it within **12 weeks** of receiving this booklet to accomplish its purpose as a teaching-tool.

Answer sheets received after the due date shall not be accepted. **We strongly feel that you should retain a copy of your assignment response to avoid any unforeseen situation and append, if possible, a photocopy of this booklet with your response.** If you have any problems or queries related to the course, you can write to us on the e-mail **slamba@ignou.ac.in**.

We wish you good luck.

Tutor Marked Assignment
PHYSICS OF SOLIDS

Course Code: PHE-13
Assignment Code: PHE-13/TMA/2023
Max. Marks: 100

Note: Attempt all questions. Symbols have their usual meanings. The marks for each question are indicated against it.

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1. Answer in brief: (2×10=20)

   i) The XeO_3 molecule has a trigonal pyramidal structure(like the Ammonia molecule). List its symmetries.

   ii) List any two missing planes for the *fcc* lattice.

   iii) What are the advantages of the neutron diffraction method?

   iv) Write down the electronic configuration of the Ge atom. What type of bonding would you expect to find in Ge?

   v) List the independent elastic constants for a cubic crystal and state their significance.

   vi) If a wave function $\psi(x)$ is to represent an electron in a crystalline solid, what should be its nature?

   vii) Write down the energy for the first excited state for electrons in a 3D box. What is the degeneracy of this energy level?

   viii) What is the effect of dopant concentration on the Fermi energy and carrier concentration of a p-type semiconductor?

   ix) In which of the following ions do you expect angular momentum quenching and why:

   Ti^{3+}, Gd^{3+}, Ni^{2+}

   x) What is the function of the quartz crystal used in a digital watch?

2. a) A plane intercepts the *x*-axis at 2a, the *y*-axis at 3b and the *z*-axis at 4c. Determine the Miller indices of this plane and the interplanar distance if the lattice parameter is 4.0 Å.

   b) A metallic element has an atomic weight of $27\,\text{u}$, density $2710\,\text{kg m}^{-3}$ and lattice constant 4.05 Å. Predict its crystal structure and calculate the nearest neighbour distance.

   c) The Bragg angle for reflection from the (110) planes in *bcc* iron is 22º for an *x*-ray of wavelength 1.54 Å. Find the lattice parameter for iron (take n = 1). What is the minimum wavelength with which the structure of this unit cell can be probed?

d) Show that the reciprocal lattice for a *bcc* lattice is an *fcc* lattice. (5×4=20)

3. a) The potential energy of a crystal is described by the expression:

$$U(r) = -4\varepsilon\left[\left(\frac{\rho_0}{r}\right)^6 - \left(\frac{\rho_0}{r}\right)^{12}\right]$$

where $\varepsilon = 3.12\times10^{-3}\,\text{eV}$ and $\rho_0 = 2.5\,\text{Å}$. Calculate the minimum potential energy.

b) The frequency of the longitudinal optical phonon for NaCl at the centre of the first Brillouin zone is $5\,\text{rad s}^{-1}$. Calculate the interatomic force constant for this material. (The atomic weight of $\text{Na} = 23\,\text{u}$ and $\text{Cl} = 37\,\text{u}$)

c) Calculate the Debye specific heat of Molybdenum at 300 K, given that its Debye frequency is $9.74\times10^{13}\,\text{rad s}^{-1}$.

d) The values of the elastic stiffness constants for GaAs are:

$$C_{11} = 1.18\times10^{11}\,\text{Nm}^{-2},\ C_{44} = 0.59\times10^{11}\,\text{Nm}^{-2} \text{ and } C_{12} = 0.54\times10^{11}\,\text{Nm}^{-2}$$

Given that the density of GaAs is $5.32\,\text{g cm}^{-3}$, determine the velocity of the transverse and longitudinal elastic waves in the [100] direction. (5×4=20)

4. a) Calculate the transition temperature for a superconductor whose energy gap is $1.65\times10^{-3}\,\text{eV}$.

b) For a Si semiconductor, $N_c = 2.8\times10^{19}\,\text{cm}^{-3}$ and $N_V = 1.04\times10^{19}\,\text{cm}^{-3}$. Determine the position of the Fermi level at room temperature for $N_A = 10^{17}\,\text{cm}^{-3}$ and $N_D = 10^{14}\,\text{cm}^{-3}$.

c) Calculate the Fermi energy and Fermi temperature for potassium metal, whose electron number density is $1.4\times10^{28}\,\text{cm}^{-3}$.

d) When 20 mA of current is passed through a specimen under a magnetic field of 0.5 Wbm^{-2}, the measured Hall voltage is 37μV. If the width of the specimen is 0.01 mm, calculate the Hall coefficient. (5×4=20)

5. a) The saturation magnetization of *fcc* Ni is $5.1\times10^5\,\text{A/m}$. If the lattice constant for Ni is 3.52 Å, calculate the net magnetic moment per Ni atom in the crystal in units of Bohr magnetons.

b) What are fusible alloys? Explain their use in safety sprinklers.

c) Explain addition and condensation polymerization with an example of each.

d) Explain, with a diagram, the operation of a photovoltaic solar cell. (5×4=20)

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