PHE-13

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

PHYSICS OF SOLIDS

Valid from January 1, 2024 to December 31, 2024

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

2024

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, 2024 to December 31, 2024**. 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/2024
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) Write down the Miller indices of a set of parallel planes which make intercepts in the ratio of $4a_1$:$4a_2$ on the *x* and *y* axes and are parallel to the z-axes.

   ii) Is it possible to carry out electron diffraction studies in air? Explain.

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

   iv) List the symmetries observed in a methane molecule.

   v) The energy of the lowest allowed level for an electron in a 1-D box is 8.0 eV. Can the electron ever have an energy of 200 eV? Justify.

   vi) Plot the variation of electrical resistivity with temperature for an ideal metal and a superconductor.

   vii) Show that the group velocity is zero at the zone boundary for a linear diatomic chain.

   viii) How does the Fermi energy of *n*- and *p*- type semiconductors change with dopant concentration?

   ix) Distinguish between substitutional and interstitial impurities with the help of a diagram.

   x) In crystal growth why does the nucleation process become more stable as the size of the nucleus increases?

2. a) Calculate the volume of the unit cell for *fcc* Pb given that its atomic radius is 0.175 nm.

   b) Determine the boundaries of the first Brillouin zone of a *bcc* structure with a lattice constant 0.20 nm.

   c) A crystal of iridium is irradiated by x-rays with a wavelength of 0.721 Å. Calculate the angle of reflection from the (111) plane, given that the lattice constant of iridium is 3.84 Å.

   d) The direct lattice vectors for a lattice are given by:

$$\vec{\mathbf{a}}_1 = a\left(\frac{\sqrt{3}}{2}\hat{\mathbf{i}} + \frac{1}{2}\hat{\mathbf{j}}\right);\ \vec{\mathbf{a}}_2 = a\left(-\frac{\sqrt{3}}{2}\hat{\mathbf{i}} + \frac{1}{2}\hat{\mathbf{j}}\right) \text{ and } \vec{\mathbf{a}}_3 = c\hat{\mathbf{k}}$$

   Obtain the volume of the primitive unit cell and the reciprocal lattice vectors. (5×4 = 20)

3. a) The binding energy of CsCl is 150 kcal mol^{-1}. If the Madelung constant for CsCl is 1.763 and the repulsive exponent n = 10.6, calculate the equilibrium interatomic distance r_e. (Take $\varepsilon_0 = 8.86 \times 10^{-12}$ Farad m^{-1}.)

b) The Young's modulus of a linear mono-atomic chain of atoms of mass 10.6×10^{-26}kg is 2.0×10^{11} Nm^{-2}. If the inter-atomic separation is 2.8 Å, calculate the force constant *K* and the maximum frequency of the atoms.

c) The Debye temperatures of NaCl and KCl are 330 K and 220 K respectively. If the heat capacity of KCl at 5 K is 3.8×10^{-2} J mol^{-1} K^{-1}, calculate the heat capacity of NaCl at 15 K.

d) Prove that in a crystal undergoing deformation, the deformed crystal axes are not mutually perpendicular. (5×4 = 20)

4. a) A divalent *bcc* solid has a lattice constant of 4.5 Å. Calculate its Fermi energy.

b) A 2-D square lattice has a side of 1.5 Å. Calculate the momentum and energy of the electron whose wave terminates at the boundary of the first Brillouin zone.

c) A semiconductor has the following parameters at temperature T = 300 K:

$E_g = 1.40$ eV; $m_e^* = 0.1\, m_e$; $m_h^* = 0.5\, m_e$.

Calculate the energy of the intrinsic Fermi level and the intrinsic carrier concentration.

d) Calculate the critical field which would destroy superconductivity at 3 K in Hg which has a critical temperature $T_C = 4.153$ K and $B_{ac}(0) = 0.0411$ T. (5×4 = 20)

5. a) Determine the magnetic moment of $Co^{2+}Fe^{3+}{}_2O_4$ which has an inverse spinel structure.

b) Calculate the mass of boron required to make a silicon crystal with 10^{16} cm^{-3} doping density, if the initial melt load of silicon is 50 kg. The density of silicon in the melt is 2.5 g cm^{-3} and boron has an atomic weight of 10.8 u. Assume that the equilibrium segregation coefficient $k_0$is constant throughout the growth process.

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

d) What are ferroelectric materials? Explain with the example of $BaTiO_3$. How are they different from piezoelectric materials? (5×4 = 20)

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