PHE-13

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

PHYSICS OF SOLIDS

Valid from January 1, 2020 to December 31, 2020

It is compulsory to submit the Assignment before filling in 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

2020

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 : ……

……

……

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, 2020 to December 31, 2020**. 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/2020
Max. Marks: 100

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

---

1. Answer in brief: (2×10=20)

   i) List the symmetries in an ethene (C_2H_4) molecule.

   ii) Draw the (111) and (101) planes for a cubic unit cell.

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

   iv) Calculate the probability for an electron to be found at an energy of $(E_F + 2k_BT)$ in a metal.

   v) Explain how a linear monoatomic chain behaves as a low pass filter.

   vi) Explain with the help of a diagram the difference between a ferromagnet, an anti-ferromagnet and a ferrite.

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

   viii) Is *x*-ray diffraction observed from the (111) and (211) planes in an *fcc* structure? Explain.

   ix) Distinguish between Type I and Type II superconductors.

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

2. 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 u. Predict the lattice crystal structure for this element.

   b) The primitive lattice vectors of a lattice are given by

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

   Determine the volume of the primitive cell and the reciprocal lattice vectors.

   c) Show that five-fold rotational symmetry is not possible in a 2-D lattice.

   d) The Bragg reflection angle from the (110) planes in bcc iron is 22° for an *x*-ray beam with λ = 1.54 Å. Calculate the lattice constant for iron (take *n* = 1). (5×4=20)

3. a) The potential energy of an *fcc* crystal lattice 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 $\varepsilon = 3.12 \times 10^{-3}$ eV and $\rho_0 = 2.82$ Å. Calculate the lattice parameter of the crystal lattice.

b) The values of the elastic stiffness constants for a material are:

$$C_{11} = 1.48 \times 10^{11}\ \text{Nm}^{-2},\ C_{44} = 0.25 \times 10^{11}\ \text{Nm}^{-2} \text{ and } C_{12} = 0.76 \times 10^{11}\ \text{Nm}^{-2}$$

Given that the density of the material is $6.5\,\text{g cm}^{-3}$, determine the velocity of the transverse and longitudinal elastic waves in the [100] direction.

c) The molar heat capacity of Titanium at 25ºC is 26.06 J $\text{mol}^{-1}\text{K}^{-1}$. Estimate its Debye temperature.

d) The inter-atomic spacing of a linear 1D lattice of atoms of mass 8.0×10^{-27} kg is 5.0 Å. The force constant is $3.0 \times 10^{-2}\ \text{Nm}^{-1}$. Calculate the maximum frequency which can be supported by this lattice. (5×4=20)

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

b) In a *p*-*n* junction in *Si*, $N_d = N_a = 10^{22}\ \text{m}^{-3}$. Calculate the built in potential for *Si* at 300 K if n_i for *Si* at $300\text{K} = 10^{16}\ \text{m}^{-3}$.

c) When 1.5 A of current is passed through a zinc specimen under a magnetic field of 2.0 T, the Hall voltage is 4.45 μV The width of the specimen is 0.03mm. Calculate the carrier concentration.

d) The critical fields for a superconductor are 1.5×10^5 T and 4.0×10^5T at 14K and 12K respectively. Calculate the superconducting transition temperature. (5×4=20)

5. a) Calculate the magnetic moment of $\text{Ni}^{2+}\text{Fe}_2^{3+}\text{O}_4$.

b) Calculate the mass of boron required to make a silicon crystal with $10^{16}\ \text{cm}^{-3}$ 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 is constant throughout the growth process.

c) Classify polymers on the basis of their structure, temperature dependent properties and mechanism of polymerization.

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

*****