No. of Printed Pages : 5 **RPHE–003**

Ph. D. (PHYSICS)

(PHDPH)

Term-End Examination

June, 2026

RPHE-003 : CONDENSED MATTER PHYSICS

Time : 2 Hours *Maximum Marks : 50*

Note : *Answer any **five** questions. Symbols have their usual meanings. You may use a calculator.*

1. (a) Define atomic packing fraction. Calculate the atomic packing fraction for a body-centred cubic (bcc) structure.

   (b) Describe the Laue method of X-ray diffraction. What are its limitations ?

5+5

2. (a) The potential energy of a system of a diatomic molecule in terms of the inter-atomic distance r is given by :

$$U = \frac{-A}{r^4} + \frac{B}{r^7}$$

where A and B are constants. Determine the equilibrium spacing of the atoms and the dissociation energy of the molecules.

(b) Derive an expression for the density of states of normal modes as a function of frequency for a 1-D chain of atoms of length L. 5+5

3. (i) Write the equation of motion for the momentum of the electron in the Drude model.

(ii) Obtain the relation between the electric field $\vec{E}$, the current density $\vec{J}$ and the magnetic field $\vec{B}$ for electron motion in the presence of electric and magnetic fields.

(iii) Define the resistivity matrix relating $\vec{E}$ and $\vec{J}$ and obtain its elements for the Hall effect experiment. 1+3+6

4. (a) State Bloch's theorem for the Eigen-states of an electron in a periodic potential. Is the Bloch wave function an Eigenfunction of the momentum operator ? Explain. 5

(b) (i) Explain how the electrical conduction in an intrinsic semi-conductor is different from that in an *n*-type semiconductor.

(ii) What is the built in potential in a *p*-*n* junction ? What are the factors on which it depends ? 5

5. (a) Explain the kind of magnetic order observed in solids with ions having :

(i) all shells completely filled. 3

(ii) a partially filled sub-shell which is one less than half-full.

(iii) a partially filled shell with non-zero total angular momentum.

(b) Calculate L, S and J for an atom with the following electronic configuration :

Manganese : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 4d^5$.

2

(c) Explain the formation of domains in a ferromagnetic material. What are the factors that influence the width of domain walls ? 5

6. (a) Explain why Heissner effect is one of the characteristic features of a super-conductor. What is the critical field of a superconductor and how does it vary with temperature ? 3+2

(b) Show that the superconducting state has a higher degree of order than the normal state. 5

7. (a) What is the difference between ballistic and normal conduction ? Using the Landauer formula, explain how conductance changes with gate voltage in a 1D ballistic conductor. 5

   (b) What are excitons ? Describe the different types of excitons. 5

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