

Ph. D. (PHYSICS)

(PHDPH)

Term-End Examination

December, 2025

RPHE-003 : CONDENSED MATTER PHYSICS

Time : 2 Hours

Maximum Marks : 50

Note : (i) Answer any **five** questions.

(ii) Symbols have their usual meanings.

(iii) You may use a calculator.

1. (a) Differentiate among crystalline, polycrystalline and amorphous solids on the basis of their atomic arrangements and properties. Give *one* example of each of these. 5
- (b) Show that the reciprocal lattice of a face-centred cubic lattice is a body-centred cubic structure. 5

2. (a) State the assumptions of Einstein's theory of heat capacity and derive an expression for the specific heat C_v . 5
- (b) Explain the main features of the dispersion curve (ω vs. k) curve) for a linear diatomic chain of atoms. 5
3. (a) Explain the free electron approximation and the independent electron approximation. What are the shortcomings of the free electron theory? 2+3
- (b) Explain the origin of the periodic potential in a crystal lattice. How is the tight binding approximation different from the nearly free electron approximation? 2+3
4. (a) Define the effective mass tensor for an energy band dispersion function $E_n(k)$. Calculate the effective mass tensor for a square lattice with the following energy dispersion : 1+4

$$E(\vec{k}) = -\alpha \left[\cos(k_x a) + \cos(k_y a) \right]$$

where a is a constant.

- (b) Derive an expression for the Fermi energy of an intrinsic semiconductor.

You may use the relations : 5

$$n_h = N_v \exp\left[-(\epsilon_F - \epsilon_V)k_B T\right]$$

$$n_e = N_c \exp\left[-(\epsilon_C - \epsilon_F)k_B T\right]$$

5. (a) Write the Hamiltonian for an atomic electron with orbital and spin angular momentum \vec{L} and \vec{S} respectively. The electron is in a magnetic field \vec{B} along the z -direction. Explain the magnetic effects arising out of the different terms in the Hamiltonian. 2+3

- (b) Write the Heisenberg's Hamiltonian for exchange interactions. What are the different kinds of spontaneous magnetic order based on exchange interactions? 5

6. (a) Derive the London equation for a superconductor and obtain an expression for the London penetration depth. 5

- (b) Explain the structural and electrical properties of Cuprate superconductors.

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7. (a) Explain how the Hall resistivity and longitudinal resistivity vary with magnetic field in integer quantum Hall effect. How is the fractional quantum Hall effect different from integer quantum Hall effect ?

3+2

- (b) Describe any two techniques for the characterization of semiconductor quantum dots.

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