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M.Sc. (CBCS) DEGREE EXAMINATION, APRIL 2025.

Third Semester

Physics — Core

CONDENSED MATTER PHYSICS

(For those who joined in July 2023 onwards)

Time : Three hours

Maximum : 75 marks

PART A — ($15 \times 1 = 15$ marks)

Answer ALL questions.

Choose the correct answer :

1. In a face-centered cubic (FCC) lattice, the reciprocal lattice is
 - (a) Body-centered cubic (BCC)
 - (b) Face-centered cubic (FCC)
 - (c) Simple cubic
 - (d) Tetragonal

2. For a hexagonal close-packed (HCP) lattice, the reciprocal lattice is
 - (a) Simple cubic
 - (b) Face-centered cubic (FCC)
 - (c) Hexagonal
 - (d) Body-centered cubic (BCC)
3. In reciprocal space, the distance between planes in the crystal lattice is related to
 - (a) The length of the reciprocal lattice vector
 - (b) The angle between direct lattice vectors
 - (c) The square of the lattice constant
 - (d) The inverse of the crystal potential
4. For a simple cubic lattice, the shape of the First Brillouin zone is
 - (a) Tetrahedral
 - (b) Spherical
 - (c) Cubic
 - (d) Rhombic dodecahedron

5. The size of the First Brillouin zone is related to
 - (a) The size of the real-space unit cell
 - (b) The distance between neighboring atoms
 - (c) The inverse of the lattice constant
 - (d) The mass of the atoms in the lattice
6. The volume of the First Brillouin zone in reciprocal space is
 - (a) The same as the real-space unit cell
 - (b) Inversely proportional to the volume of the unit cell in real space
 - (c) Equal to the volume of the real-space lattice
 - (d) Directly proportional to the number of atoms in the unit cell
7. The Luttinger's theorem in the context of the Fermi surface states
 - (a) The Fermi surface encloses a volume proportional to the total number of electrons in the system
 - (b) The Fermi surface must always be spherical
 - (c) The Fermi surface encloses the smallest possible volume
 - (d) The Fermi surface is independent of the electron concentration

8. In a crystal with a periodic potential, the Fermi surface is often
 - (a) A perfect sphere
 - (b) Distorted due to the interaction between electrons and the periodic lattice
 - (c) Independent of the crystal structure
 - (d) Flattened at the origin of reciprocal space
9. In a free electron model, the shape of the Fermi surface in 3D is
 - (a) Cubic
 - (b) Spherical
 - (c) Ellipsoidal
 - (d) Rhombic dodecahedron
10. The boundary between two ferromagnetic domains is known as
 - (a) Domain wall
 - (b) Magnetic barrier
 - (c) Magnetic junction
 - (d) Magnetic pole

11. The Hysteresis loop is a graphical representation of
 - (a) The temperature dependence of magnetization
 - (b) The relationship between magnetic field strength and magnetization
 - (c) The relationship between electric field and polarization
 - (d) The thermal energy of a ferromagnetic material
12. The size of ferromagnetic domains is typically on the order of
 - (a) Nanometers
 - (b) Micrometers
 - (c) Millimeters
 - (d) Centimeters
13. In the context of the DC Josephson effect, the critical current I_c is defined as
 - (a) The maximum current flowing through the junction without a voltage
 - (b) The current that leads to complete breakdown of superconductivity
 - (c) The current flowing due to thermal fluctuations
 - (d) The average current over one complete cycle of oscillation

14. The AC Josephson effect can be used to create
 - (a) Low-frequency amplifiers
 - (b) High-frequency oscillators
 - (c) DC power supplies
 - (d) Superconducting qubits
15. In an AC Josephson junction, the oscillation frequency increases with
 - (a) Increasing temperature
 - (b) Decreasing applied voltage
 - (c) Increasing applied voltage
 - (d) Decreasing critical current

PART B — ($5 \times 4 = 20$ marks)

Answer ALL questions choosing either (a) or (b).

Each answer should not exceed 600 words.

16. (a) Obtain Miller indices for a plane having intercepts $a/2$, b and c .

Or

- (b) Prove that the crystal cannot have five fold symmetry.

17. (a) Obtain the relation between group and phase velocities.

Or

- (b) Explain Phonon momentum.

18. (a) Derive the three-dimensional wave function for the free electron gas and obtain its eigen values.

Or

- (b) Describe the experimental methods in Fermi surface studies.

19. (a) Explain the difference between the terms 'Curie temperature' and Neel temperature.

Or

- (b) Distinguish between ferro and antiferromagnetic materials.

20. (a) What are Squids? What are their uses?

Or

- (b) What is Meissner effect? Show that superconductors are perfect diamagnet.

PART C — (5 × 8 = 40 marks)

Answer ALL questions, choosing either (a) or (b).

Each answer should not exceed 600 words.

21. (a) Explain the structure and properties of liquid crystals.

Or

- (b) Explain the cohesive energy of ionic crystals.

22. (a) Obtain an expression for the specific heat capacity of a solids on the basis of Debye's theory. How far do the results from these theories agree with experimental data?

Or

- (b) Explain the quantization of lattice vibrations.

23. (a) State and prove Bloch theorem.

Or

- (b) Explain the De Hass-Van Alphen effect.

24. (a) Give an account of quantum theory of ferromagnetism.

Or

- (b) Explain the domain theory of ferromagnetism.

25. (a) Based on tunneling explain the d.c and a.c Josephson effects.

Or

- (b) Explain super conductivity. Give an account BCS theory on superconductivity.