M.Sc. Examination, 2018
Semester – III
Physics
Course: MPC-352
(Condensed Matter Physics-I)

Time: Three Hours **Full Marks: 40**

Questions are of value as indicated in the margin.
Answer ***any four*** questions.

1.a) Assuming the interacting spin to be large obtain the low energy magnon excitation of the ferromagnetic Heisenberg spin system with only nearest neighbour interaction for a three dimensional cubic lattice. 7

b) Obtain the temperature dependence of the specific heat at low temperatures for the large spin ferromagnetic Heisenberg spin system in the periodic cubic lattice with only nearest neighbour exchange interaction. 3

2. a) State and explain Wick's theorem. 2

b) Let c_k and $c_k^\dagger$ are the annihilation and creation operators for the electrons for the state $|k>$. Write down the Hamiltonian for a system of interacting elections in terms of c_k and $c_k^\dagger$. 1

c) Write down Greens' function for the interacting electronic system in the interaction picture. 2

d) Draw the Feynman diagram for the self energy of the interacting electronic system in the Hertree Fock approximation 2

e) Evaluate the corresponding self-energy in the Hartree approximation. 3

3. a) Obtain the energy dispersion for electrons in solids in the tight-binding approximation for a one dimensional chain and calculate the density of states of this system. 4+2

b) The method of orthogonalised plane waves (OPW) is very often used to make band structure calculation for electronic states in metals. It explains why the nearly free electron approximation can be used although the actual lattice potential acting on the electrons is not weak. Discuss the essential physical ideas and mathematical formalism involved in this method. 4

4. Show that the charge density of a free electron gas around a static impurity with charge Q possesses a long range oscillation (Friedel oscillation) with decreasing its amplitude with distance. 10

5. a) Show that an Abelian group of order h has h one-dimensional representations and no others. For the special case of cyclic groups, find the representations. 4

b) Consider a periodic potential with the element A representing a displacement through one period. Let the boundary conditions for the Schrödinger equation be such that they are also periodic over h periods of the potential. From group theoretical considerations derive Bloch's theorem for this case. 6

6. a) Consider an electron moving in the potential field of three protons located at the corners of an equilateral triangle. Form the character table for the relevant group. 7

b) A representation of the above group is given below:

$$E = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix},\ A = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix},\ B = \begin{pmatrix} -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{\sqrt{3}}{2} & \frac{1}{2} \end{pmatrix},$$

$$C = \begin{pmatrix} -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ -\frac{\sqrt{3}}{2} & \frac{1}{2} \end{pmatrix},\ D = \begin{pmatrix} -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{\sqrt{3}}{2} & -\frac{1}{2} \end{pmatrix},\ F = \begin{pmatrix} -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ \frac{\sqrt{3}}{2} & -\frac{1}{2} \end{pmatrix}$$

How will P_D (symbols have the usual meanings) transform the eigenfunction belonging to the second row of this representation? 3

7. From k-space analysis of motion of an electron in a uniform magnetic field and the relation between the area of a closed orbit in k-space and the cyclotron frequency ω_c, derive an expression for the cyclotron mass m_c^*. Can it be negative? 8+2