M.Sc. 2nd Semester Examination, 2021

PHYSICS

(Statistical mechanics-I and Nuclear Physics-II)

Paper: 204C

Course ID: 22454

Time: 2 Hours **Full Marks: 40**

Candidates are required to give their answers in their own words as far as practicable.
The questions are of values indicated in the margin.

Unit-I

1. **Answer *any three* of the following questions:** 2x3= 6
   a) What is equipartition theorem? What is the physical significance of chemical potential? 2
   b) What do you mean by statistical equilibrium? 2
   c) Define density matrix in quantum statistics. 2
   d) Hamiltonian of a particle of mass "m" is given by $H = p^2/2m - aq^2/2$; a>0. Find the phase space trajectory. 2
   e) Under what condition the FD and BE distribution functions tend to MB distribution? 2

2. **Answer *any two* of the following questions:** 4x2 = 8
   a) A collection of N two level system with energies 0 and E>0 is in thermal equilibrium at temperature T. For T $\rightarrow$ infinity, calculate the specific heat. 4
   b) Consider a system maintained at temperature T, with two available energy states E1 and E2 each with degeneracy g1 and g2, respectively. If p1 and p2 are the probabilities of occupancy of the two energy states, calculate the entropy of the system. 4
   c) Lagrangian of a free particle in one dimension of mass "m" is given by $L = -[1-(dx/dt)^2]^{1/2}$. If such a particle is acted upon by an external constant force in the direction of its motion, find the phase space trajectories. 4
   d) Obtain the relationship between energy fluctuation and number fluctuation for grand canonical ensemble. 4

3. **Answer *any one* of the following questions:** 6x1 = 6
   a) (i) Find out the partition function for quantum harmonic oscillator and hence calculate the thermo-dynamical quantities such as free energy, entropy, average energy and heat capacity and draw them graphically as a function of temperature.
   (ii) Show that for pure state $Tr[\rho] = 1$, where ρ is density matrix operator. 5+1 = 6

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b) (i) Consider a system of 2N non-interacting spin ½ particles each fixed in position and carrying a magnetic moment "μ". The system is immersed in an uniform magnetic field B. calculate the number of spin up particles for which the entropy of the system will be maximum.

(ii) A particle in thermal equilibrium has only 3 possible states with energies –E, 0, +E. If the system is maintained at a temperature $T >> E/k_B$, calculate average energy of the particle. 4+2 = 6

Unit-II

4. **Answer *any three* of the following questions:** 2x3= 6

a) What is Cherenkov radiation? 2

b) Why the NaI crystal is activated with Thallium (Tl) when used as a scintillator? 2

c) Why coulomb correction is necessary in Fermi's theory of beta decay? 2

d) Can H_2O be used as moderator in nuclear fission reactor? Explain. 2

e) What kind of probe is to be used to go inside the quark? 2

5. **Answer *any two* of the following questions:** 4x2 = 8

a) State the characteristics of the strong, weak and electromagnetic interactions. What do you mean by resonance particles? 3+1=4

b) Discuss the working principle of an inorganic scintillator detector (with example) for gamma detection. Draw the energy spectra when 1 and 2 MeV gamma are incident on the inorganic scintillator detector. 3+1 =4

c) Draw a schematic diagram of nuclear fission reactor and discuss briefly each component of the reactor. Is it possible to make a fission reactor with fast neutron? Justify. 3+1=4

d) What do you mean by quark confinement? Give an evidence for the color degree of freedom of quarks. If $0 \rightarrow 0$ gamma transition could occur, then what would be the consequence? Explain. 1+1+2=4

6. **Answer *any one* of the following questions:** 6x1 = 6

a) What do you mean by β end point energy? Compare the β^+ and β^- energy spectrum graphically. Derive the kinetic energy distribution for a β decay and show graphically. 1+1+4 = 6

b) Discuss how do you detect neutrinos? Write down a few names of research facilities for neutrino detection in the world. Why is the penetrating power of a neutrino much greater than that of a photon of the same energy, inspite of the fact that they are both charge less and massless? 3+1+2=6