P.G. Semester-II Examination, 2023

PHYSICS

Course ID : 22454 **Course Code : PHS-204C**

Course Title : Statistical Mechanics-I and Nuclear Physics-II

Time : 2 Hours Full Marks : 40

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

UNIT-I

1. Answer any **three** of the following questions : 2×3=6

   a) Construct the canonical partition function of a system of localized spin-1/2 particles.

   b) What is an ensemble? Explain.

   c) Constitute the partition function of ten quantum harmonic oscillators.

   d) Prove that $Tr\left(\rho^2\right) \leq 1$, where ρ is the density matrix operator.

   e) Consider 100 nonlinear triatomic molecules. What will be the dimension of the phase space and the minimum accessible volume?

2. Answer any **two** of the following questions : 4×2=8

   a) For a system of spin-1/2 particles in a magnetic field $\vec{H}$, find the following:

      i) Helmholtz free energy,

      ii) Average energy at low and high temperature,

      iii) Average magnetic moment at low and high temperature,

      iv) Susceptibility. 1+1+1+l=4

   b) Consider a system of N localized atoms at temperature T. The quantized vibrational energy levels of each atom is given by

   $$\in_n = \left(n + \frac{1}{2}\right)\hbar\omega, n = 0,1,2,...$$

      i) Show that the average energy per atom of this system is $U = \frac{1}{2}\hbar\omega + \frac{\hbar\omega}{e^{\beta\hbar\omega} - 1}$

      ii) Show that the pressure of the system vanishes. 2+2

   c) i) Write down an expression of canonical partition function of two identical fermions in a system with four energy levels E, 2E, 3E and 4E (E>0).

ii) Derive the expression of entropy of a three level system having equal populations in each level. 2+2

d) i) Define the density matrix in quantum statistics.

ii) Derive the equation of state of a system, i.e., obtain the quantum mechanical Liouvelli's theorem. 1+3

3. Answer any **one** of the following questions : 6×1=6

a) i) Consider a two-level system having energy levels ε and $-\varepsilon$. Discuss the nature of the specific heat at constant volume of the system at low and high temperature if the system is populated with N non-interacting particles.

ii) From Combinatorial point of view derive an expression of entropy of the above system. Hence, explain the concept of negative temperature using entropy vs. average energy curve. 2+4

b) Starting from the quantum distribution function, prove that the pressure exerted by a Fermi gas is greater than that of the Bose gas (you may consider a quantal gas). Comment on the result. 6

UNIT-II

4. Answer any **three** of the following questions : 2×3=6

a) What is the experimental evidence for the existence of neutrino particle?

b) What is Cherenkov radiation?

c) How are the prompt neutrons produced in a fission reaction? What is beta delayed neutron?

d) What is Photo Multiplier Tube (PMT)? Draw the schematic diagram of a PMT.

e) What are the quark composition of k and π meson?

5. Answer any **two** of the following questions : 4×2=8

a) What are the single escape and double escape peak in a gamma ray energy spectrum of a scintillator detector? Compare the energy spectrum when gamma ray (2.04 MeV) is incident in a very small volume and big volume inorganic scintillator detector? 2+2

b) Calculate the energy released in fission and fusion from the binding energy per nucleon vs A graph, where A is mass number of a nucleus. Why D+T is more favorable to be used in fusion reactor compared to D+D reaction? 2+2

c) Why coulomb correction is necessary in Fermi's theory of beta decay? Compare (graphically) the energy distribution spectrum for β^+ and β^- decay. Discuss how do you measure the mass of a neutrino from β energy spectrum? 2+1+1

d) Discuss the working principle of a semiconductor detector for gamma detection? 4

6. Answer any **one** of the following questions : $6 \times 1 = 6$

a) Discuss how the charge particle losses its energy while passing through a medium. Can you use H_2O as moderator in fission reactor? Explain. 4+2

b) What do you mean by β end point energy? Discuss Wu's experiment in support of non-conservation of parity in beta-decay. 1+5

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