M.Sc. 4th Semester Examination, 2024

PHYSICS

PAPER – PHS-402.1 & 402.2

Full Marks : 50

Time : 2 hours

Answer **all** questions

The figures in the right hand margin indicate marks

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

PAPER — PHS-402.1

(*Statistical Mechanics*-II)

[Marks : 20]

GROUP–A

Answer any **two** questions from the following : 2 x 2

1. Write down the expression for free energy of Fermi gas under quantization by magnetic field.

2. Distinguish between condensation of normal liquid and BE condensation.

3. Prove that average energy of relativistic electron is $\frac{3}{4}E_F(0)$.

4. For 2D Debye solid, find an expression of lattice specific heat at low temperature.

GROUP–B

Answer any **two** questions from the following : 4×2

5. Show that for a 2D electron gas the number of electrons per unit area

$$n = \frac{4\pi m k_B T}{h^2} \log \left(1 + e^{\beta E_F}\right).$$

6. Show that susceptibility can be expressed in terms of correlation function.

7. Show that diffusion of a particle can be expressed in terms of auto-correlation function.

8. Prove that in BE condensation number of particles in excess of ground state is

$$\left(\frac{T}{T_0}\right)^{3/2} \frac{B_{3/2}(\alpha)}{B_{3/2}(0)} \quad where \quad \alpha = -\mu B.$$

GROUP–C

Answer any **one** question from the following : 8×1

9. A lattice of $(N + 1)$ sites has spins $S_i = \pm 1$ at each site, all of which are acted on by a magnetic field. The Hamiltonian

$$H = -h \sum_{i=0}^{N} S_i - J \sum_{i=1}^{N} S_i S_0$$

(*i*) Calculate the Partition function $Q(T, N)$.

(*ii*) Average energy $\langle E \rangle$

(*iii*) Find $\langle S_i \rangle$ and $\langle S_0 S_i \rangle$ for $h \to 0$ with $J \neq 0$ and $J \to 0$ with $h \neq 0$.

2 + 2 + 2 + 2

10. If

$$E = - \sum_{i=1}^{N-1} J_i \; S_i \; S_{i+1}$$

for Ising spin.

(*i*) Calculate $\langle S_k \, S_{k+r} \rangle$

(*ii*) Also show that correlation function

$$G(r) = \prod_{k=1}^{r} \tan h \;\; \beta \; J_{K+r-1}.$$

4 + 4

PAPER – PHS-402.2

(*Nuclear Physics*-II)

[Marks : 20]

GROUP–A

Answer any **two** of the following : 2×2

1. Why the experimental study of *p-p* scattering is capable of much higher accuracy than that of *n-p* scattering ?

2. Estimate the Fermi energy of protons in the centre of $_{92}U^{238}$ nucleus. Assume the density of nuclear matter at the centre of the $_{92}U^{238}$ nucleus to be 2×10^{38} nucleons. cm^{-3}.

3. Find the spin-parity of $_{19}K^{42}$ nucleus using shell model.

4. Show that the lighter nuclei are more effective moderators than the heavier nuclei.

GROUP–B

Answer any **two** of the following : 4×2

5. A tritium gas target is bombarded by a beam of monoenergetic protons of kinetic energy 3 MeV. What is the kinetic energy of the neutrons emitted at 30° to the incident beam ? Given, the atomic masses :

$$M\left({}_1^1H\right) = 1.007825u\,,\; M\left({}_1^3H\right) = 3.016049u$$

$$\text{and } M\left({}_2^3He\right) = 3.016029u.$$

6. Prove in case of deuteron that the probability of finding neutron and proton within the inter-nucleon force is only about 30%.

7. In case of neutron-nuclear interaction, most materials can be made into mirros which reflect (repel) neutrons even though fundamental neutron-nuclear interaction is always attractive. Why is this so ?

(*Continued*)

8. Show how far the liquid drop model is successful in explaing why U-235 is fissile to slow neutrons but U-238 is not.

GROUP – C

Answer any **one** of the following questions : 8×1

9. (*i*) Show that the critical energy of deformation for causing fission is a linear function of Z^2/A for light nuclei. 4

(*ii*) There is a spin-orbit term $\vec{L}.\vec{S}$ in the nucleon-nucleon interaction. Explain why there can not be a term like $\vec{r}.\vec{L}$. 2

(*iii*) Calculate the most probable energy of neutrons at temperature 20°C. 2

10. (*i*) Deduce the Breit-Weigner one level formula for spin-less nuclei at very low energy. 5

(*ii*) Nickel-59 has an absorption cross-section of 4.8 barns and a scattering cross-section of 17.5 barns. Compute the moderating ratio for nickel. How many collisions would be needed to thermalize a 1MeV neutron ? 3

[Internal Assessment — 10 Marks]