2021

PHYSICS

PAPER-II

Time Allowed — 3 Hours *Full Marks — 200*

If the questions attempted are in excess of the prescribed number, only the questions attempted first up to the prescribed number shall be valued and the remaining ones ignored.

*Answers may be given either in **English** or in **Bengali** but all answers must be in one and same language.*

Group-A

Answer *any six* questions.

1. State and prove the equipartition theorem. 2+8=10

2. For a massless extreme relativistic gas of N particles find the partition function. Comment on the validity of the equipartition theorem in this particular case. 7+3=10

3. Find the entropy of a non-interacting gas using microcanonical ensemble. 10

4. (a) Draw the circuit diagram to study the common-emitter mode characteristics of a transistor.

   (b) Draw the typical common-emitter output characteristics of a p—n—p transistor and explain those. 5+5=10

5. The saturation current density of a p—n junction germanium diode is 250 mA/m^2 at 300°K. Find the voltage that would have to be applied across the junction to cause a forward current density of 10^5 A/m^2 to flow. 10

6. (a) Draw the energy spectrum of the β-particle in β-decay. Explain the origin of its continuous nature.

   (b) Indicate the fundamental interaction through which the following processes occur: (3+4)+3=10

   (i) $n \rightarrow p + e^- + \bar{\nu}$

   (ii) $p + p \rightarrow p + p + p + \bar{p}$

   (iii) $\gamma \rightarrow e^+ + e^-$

7. (a) Discuss the evidences in favour of the nuclear shell model.

   (b) Explain how the liquid drop model can explain the phenomenon of nuclear fission. 5+5=10

8. (a) Define group velocity and phase velocity. Obtain a relation between the two.

   (b) Show that the eigenvalues corresponding to a hermitian operator is real. (2+2+4)+2=10

9. Using Debye's theory, find out an expression for specific heat of solids. Explain how it differs from classical theory. 7+3=10

Group-B

Answer *any seven* questions.

10. (a) Calculate the canonical partition function Q_1 for a single classical simple harmonic oscillator with Hamiltonian

$$H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2$$

   (b) Hence compute the partition function for N distinguishable oscillators as $Q_N = Q_1^N$. Find S, P, μ, U, C_p and C_V. Comment on the validity of equipartition theorem. The symbols have their usual meaning. 8+12=20

11. In the theory of paramagnetism, the Hamiltonian can be written as

$$H = -\sum_{i=1}^{N} \vec{\mu}_i . \vec{B}$$

   (a) Treating the system classically find the magnetic moment at a temperature T.

   (b) Treat the system quantum mechanically where $\vec{\mu} = g_J \mu_B \vec{J}$. The z-component of $\vec{J}$ can be $m = -J, -J+1, \ldots\ldots\ldots\ldots, J-1, J$. Find the magnetic moment at a temperature T and obtain the expression for the Curie constant at high temperature. 10+10=20

12. (a) For a two level system, with total number of particles N, energy U and allowed energy levels 0 and ϵ, find the U as a function temperature T.

   (b) Consider a classical gas of hard spheres of diameter σ. When a particle is added to the system of N particles, the volume available to the new particle is not V but somewhat less. Assuming that $N\sigma^3 << V$, determine how the number of microstates Ω (N, V, E) depends on V. Also show that as a result of this, V in the gas law $PV = Nk_BT$ gets replaced by $(V - b)$ where b is equal to four times the actual space occupied by the sphere. 8+12=20

13. (a) State four characteristics of an OP AMP.

   (b) Draw the circuit diagram of a non-inverting amplifier using an OP AMP. Derive an expression for the gain of the amplifier.

   (c) Draw the circuit diagram of an integrator using an OP AMP. Derive an expression for the output voltage. 4+(4+4)+(4+4)=20

14. (a) Prove the following Boolean identities:

(i) $\overline{AB+BC+CA}=\bar{A}\bar{B}+\bar{B}\bar{C}+\bar{C}\bar{A}$

(ii) $A(A+\bar{B}C)+A(\bar{B}+C)=A$

(iii) $(A+\bar{B})(\bar{A}+C)=AC+\bar{A}B$

(b) Design a logic circuit to implement the following:

$$Y=ABC+\bar{A}B+\bar{A}C$$

(c) Sketch the circuit for a NOR gate using diodes and transistors and explain its working.

(4+4+4)+3+5=20

15. (a) Write down the semi-empirical mass formula. Explain its different terms. Explain from the mass formula why odd-odd nuclei are rare in nature.

(b) Draw the $I_3 - Y$ plot of the octet of pseudoscalar mesons indicating the respective particles.

(3+8+2)+7=20

16. (a) Write down the one dimensional Schroedinger equation for a particle under a step potential given as $V = 0$ for $x < 0$ and $V = V_0$ for $x > 0$.

(b) State the boundary conditions.

(c) Solve the equation for both the regions assuming the particle energy $E > V_0$.

(d) Find the probability current density for incident, reflected and transmitted waves.

(e) Find the transmission and reflection coefficient. 2+2+6+6+4=20

17. (a) Sketch a one dimensional harmonic oscillator potential. Write down the energy eigenvalues. Sketch the wave function for the first three states.

(b) Consider a two dimensional symmetric harmonic oscillator with frequency ω. Find out the degeneracy of the state with energy $5\hbar\omega$.

(c) Write down coordinate space representation of the operators L_x and L_y. Find their commutation relations using the commutation relation of position and momentum.

(d) Show that the eigenfunctions corresponding to two different eigenvalues of an operator are orthogonal to each other. (2+2+3)+2+(2+4)+5=20

18. (a) Discuss the band structure of metals, conductors and semiconductors.

(b) Obtain an expression for Hall Voltage in a intrinsic semiconductor sample.

(c) Distinguish between ferromagnetism, diamagnetism and paramagnetism. 8+6+6=20

19. (a) Describe the feature of anomalous Zeeman effect that could not be explained classical theory.

(b) What are Stokes and anti-Stokes lines?

(c) The uncertainty in the mass measurement of an elementary particle is 1 MeV. Estimate its lifetime.

(d) A $^{7}_{3}Li$ nucleus is bombarded with protons and α-particles are emitted in the reaction. Calculate the kinetic energy of the α-particle assuming the kinetic energy of the bombarding proton to be negligible. [Given M($^{7}_{3}Li$) = 7.016004 a.m.u., M(p) = 1.007826 a.m.u. and M(α) = 4.002603 a.m.u.]

(e) What is Meissner effect in superconductivity? 6+4+3+4+3=20
