CSM – 59 / 15
Physics
Paper – II

Time : 3 hours

Full Marks : 300

The figures in the right-hand margin indicate marks.

Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and ***three*** *of the remaining questions, selecting at least* ***one*** *from each Section.*

Section – A

1. Answer any **three** of the following :

   (a) A particle of mass 'm' bounces elastically between two infinite plane walls separated by a distance $2 \times 10^{\{-10\}}$mts. (i) find the lowest energy state of the particle. If the separation between the walls is increased adiabatically to twice its distance, calculate

the change in energy and (ii) what is the expectation value of the momentum of the particle in the ground state. 20

(b) (i) Find the eigenfunctions and eigenvalues for the operator $\sin\left(\frac{d}{d\phi}\right)$. 10

(ii) Prove that $(\sigma \cdot A)(\sigma \cdot B) = (A \cdot B) I + i\sigma \cdot (A \times B)$, where '$\sigma$' are the Pauli's spin operator. 10

(c) At time $t = 0$, the state of a free particle is satisfied by $\psi(x, 0) = A\exp(-x^*x + ikx)$. Find the factor A and the region where the particle is localized. Determine the probability current density J. 20

(d) Give any four experiments which showed the inadequacy of classical mechanics.

2. (a) (i) State the uncertainty principle and derive the uncertainty relation between Δp, Δx. 10

(ii) Given $\psi(x \cdot t) = A\exp[i\phi(x, t)]$, find its probability current density. 4

(iii) Write a note on the normalization of a state in the case of both continuous and discrete variable. 6

(b) (i) Obtain the energy values of a linear harmonic oscillator by constructing ladder operators and show that the ground state is a minimum uncertainty state. 10

(ii) The Andromeda nebula, at a distance of $2 \times 10^{\{22\}}$ mts from the earth, radiates $8 \times 10^{\{27\}}$ watts in spectral line of frequency 1,420 Mhz. Estimate the number of photons received per second when the nebula is observed by a radio telescope of area 100 $mts^{\{2\}}$. 10

(c) (i) Write the time independent Schrodinger equation in spherical coordinates and obtain the solutions for its angular part. Show that the radial equation is identical in form to the one dimensional Schrodinger equation with an effective potential. 10

(ii) Can any two components of angular momentum operator J be measured simultaneously ? Explain. 10

3. (a) With a neat diagram, explain Stern-Gerlach Experiment. 10

(b) Consider the hydrogen atom in the $D_{5/2}$ state. What are the different possible orientations of the J vector space. 10

(c) Consider two electrons, one in the 4p and the other in the 4f subshell. Obtain the possible L, S and J values and the term symbols for this two electron system. 15

(d) For nitrogen, find the values of L and S for the ground state. 5

(e) Explain Zeeman effect with a neat diagram and obtain the expression for Lande g factor. 20

4. (a) Explain the principle of NMR. List the basic requirements of a typical NMR spectrometer. 20

(b) (i) Explain Raman effect with the help of an energy level diagram. 15

(ii) Irradiation of carbon tetrachloride by 4,359 Å radiation gives Raman lines at 4,400 ; 4,419 and 4,447 Å. Calculate the Raman shift for each of these lines in cm^{-1}. 5

(c) Explain the vibrating diatomic molecule with energy levels. 20

Section – B

5. Answer any **three** of the following :

(a) (i) What do you understand by the terms distribution of nuclear charge and distribution of nuclear matter ? Discuss the method of determining nuclear radius by electron scattering. 10

(ii) Derive a relation between spin and magnetic moment on the basis of single particle model. Explain anomalous magnetic moment of neutron. 10

(b) (i) What are the evidences of magic numbers ? On the basis of the extreme single particle shell model, obtain the ordering of the energy levels for a nucleus moving in an infinite square well potential. 12

(ii) Discuss stability of isobars on the basis of the liquid drop model of the nucleus. 8

(c) (i) Describe the condition for nuclear chain reaction. Obtain the condition for critical size for the thermal reactor. 10

(ii) Explain briefly the Non-conservation of parity in weak interactions. 10

(d) Explain the basic assumptions of the liquid drop model. Derive the Weizsacker's semi empirical mass formula for a nucleus. Discuss the contribution of each term. 20

6. (a) (i) Discuss important conservation laws operating in the various interactions between elementary particles. Wherever possible, mention the symmetries behind the conservation laws. 15

(ii) Write briefly on Quark Model. Comment on Quark Model of Hadrons. 10

(iii) Write a note on CP Violation in weak interaction. 5

(b) (i) Discuss the concept of unifications of forces. 15

(ii) Explain the features of Plank mass, Plank length, Plank time and Plank energy with examples. 15

7. (a) (i) With a neat diagram, represent (110), (310) and (111) planes in cubic crystal. Find the relation between d(hkl) and lattice constant for a cubic crystal. 6

(ii) On the basis of tightly bound electron approximation, obtain an expression for energy of electron. Show that the energy gap is 12x Gamma in the case of cubic crystal. 10

(iii) Obtain an expression for the maximum energy of an electron in a cubic crystal in terms of lattice constant. 4

(b) (i) Explain, with relevant theory, the temperature variation of electrical conductivity in the case of an intrinsic semiconductor. 8

(ii) For an extrinsic semiconductor, with appropriate theory, explain the temperature variation of carrier concentrations. 8

(iii) Consider a sample of n type Si with $N - \{d\} = 10^{\{21\}}/m^3$. Find the extrinsic carrier concentrations at 300 K. Given the number of intrinsic carrier concentration is 9.8 times $10^{\{15\}}/m^{\{3\}}$. 4

(c) (i) List the properties of type – I superconductors. 6

(ii) On the basis of suitable theory, explain AC and DC Josephson effect in superconducting junctions. 10

(iii) Estimate the London penetration depth from the following data : 4

$m = 17.3\times 10^{\{-31\}}$ kg ; $n = 3.7\times 10^{\{28\}}/m^3$; $e = 1.6\times 10^{\{-19\}}$C.

8. (a) Discuss construction and working of Phase-shift oscillators and Hartley oscillators. Mention their applications. 20

(b) Explain De Morgan's laws. Explain the construction and Truth table of OR, AND and X-OR gate. 10

(c) Explain the construction and advantages of super-heterodyne receivers. 15

(d) Give the theory of ionospheric propagation of radio frequency waves. 15