B. Sc. Physics Examination, 2023

(3rd Year, 1st Semester)

Atomic, Molecular and Laser Physic

Paper – Sc/PHY/UG/DSE/TH/02/A2

Time : Two hours Full Marks : 40

Answer any FOUR Questions selecting ***two*** from question Nos. 1 to 3 and ***two*** from the rest

1. (a) Briefly discuss the concept of phase space with suitable example. (b) What was the explanation for the occurrence of fine structure of atomic spectral lines proposed by Sommerfeld? (c) Show that for Hydrogen atom a state with principal quantum number is n^2 fold degenerate and explain the origin of the degeneracy in this system. 3½+3½+3

2. (a) The result of the Stern-Gerlach experiment substantiated the concept of space quantization – Explain. (b) Discuss the role of Pauli's exclusion principle in arranging electrons in an atom. (c) The trajectory of an electron can become a rosette – Explain. 3½+3½+3

3. (a) What do you mean by *LS*- and *jj*-coupling? When do they occur? (b) Derive the expression for Landé *g*-factor considering the interaction of orbital and spin angular momenta. (c) An atomic state is denoted by $^4D_{5/2}$. Write down the values of *L*, *S* and *J*. What should be the minimum number of electrons involved for this state? 2½+5+2½

4 (a) For a two-level system in thermal equilibrium establish the threshold condition for laser action in terms of the passive cavity life time (τ_c), line shape function [$g(\omega)$] and spontaneous lifetime of the species associated with the transition from state **2** to state **1**. (b) At thermal equilibrium, estimate the ratio of Einstein's "A" and "B" coefficients. Comment on your result. (c) Find the ratio of population of the two states in a He-Ne laser that emit light of wavelength 6328 Å at 300 K. [Given: Boltzmann Constant $k = 1.38 \times 10^{-23}$ J/K]. 4+3+3

5. (a) From quantum mechanical approach, show that the rotational energy of a diatomic molecule (assuming it to be a rigid rotor) is expressed as $\varepsilon_J = BJ(J+1)$ cm^{-1}, where B is the rotational constant and J is the rotational quantum number. (b) The moment of inertia of CO molecule is 1.46×10^{-46} Kg-m^2. Calculate the energy in eV and the angular velocity in the lowest rotational energy level of the molecule ($h = 6.62 \times 10^{-34}$ Joule-second). (c) Will all linear diatomic molecules show rotational spectrum? Comment on your answer. 5+3+2

6. (a) What is "LCAO" approximation? What are the conditions to be satisfied by the contributing atomic orbitals to generate an effective molecular orbital? (b) For an oblate symmetrical top molecule show the energy ε_j for the j th energy level in spectroscopic unit is expressed as $\varepsilon_J = BJ(J+1) + (A-B)\mathrm{K}^2$ cm^{-1}, where symbols have their usual meanings. Hence obtain a relation between "A" and "B" for such molecule. (c) What is the basic idea behind Born-Oppenheimer (BO) approximation? (b) How the Hamiltonian of the electrons and the nuclei of a molecule are represented following BO approximation? Write the corresponding Schrödinger equations in terms of electronic and nuclear wavefunctions. 3+3+4