7. *(a)* What do you mean by spontaneous and stimulated emissions? Hence define the terms Einstein's A and B coefficients in case of a two level system. Comparing the result with the Planck's radiation formula and estimate the relations between the A and B coefficients.

(b) In the $2p \rightarrow 1s$ transition in the Hydrogen atom, the life time of the $2p$ state for spontaneous emission is estimated to be 6×10^9 / sec. If the frequency (ω) of the transition is 150 cycles per second, calculate the Einstein's B coefficient associated with the stimulated emission of radiation from the above referred energy states. [Consider the refractive index (n_0) to be unity].

(2+3+2)+3 **(CO4)**

(OR)

8. *(a)* In an optical resonator of length d consisting of a pair of mirrors with reflectivities R_1 and R_2, show that the average loss α_1 and the average gain α in the medium per unit length is related through the following expression :

$$-\alpha_1 \geq \alpha - \frac{1}{2d} \ln R_1 R_2$$

Hence show that for two level system in thermal equilibrium, the threshold condition for laser action is inversely proportional to both the passive cavity life time (τ_c) and line shape function $g(\omega)$.

(b) If the coherence time of a laser beam is 10^{-3} sec, calculate the corresponding coherence length. Comment on the statement. (4+3)+(2+1) **(CO4)**

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B. SC. PHYSICS EXAMINATION, 2025

(3rd Year, 1st Semester)

PAPER : SC/PHY/UG/DSE/TH/02/A2

(ATOMIC, MOLECULAR AND LASER PHYSICS)

Time : *Two hours* *Full Marks* : 40

Answer **all** questions.

1. *(a)* What is phase space? Draw the phase space diagram showing the radial motion of the electron according to Sommerfeld.

(b) Give a brief description of anomalous Zeeman Effect with necessary energy level diagram clearly mentioning the polarization.

(c) Write down the spectral notation for a single electron atom having principal quantum number $n = 3$. Why ground state of an atom is always a singlet?

3+(3+1)+3 **(CO1)**

(OR)

2. *(a)* What is Born-Oppenheimer (BO) approximation?

(b) Write the general Hamiltonian for a polyatomic molecule.

(c) Show how BO approximation is applied to represent the Hamiltonian of the electrons and the nuclei of a molecule. Write the corresponding Schrödinger equations in terms of electronic and nuclear wave functions.

(d) Hence obtain the total molecular wave function for the molecule. 2+2+3+2+1 **(CO1)**

3. *(a)* The trajectory of an electron can become a *rosette* — explain.

(b) What was the hypothesis of electron spin? Explain the role of magnet pole pieces in Stern-Gerlach experiment.

(c) Calculate the total number of electronic energy levels for a given principal quantum number n.

(d) Obtain the precessional frequency of an electron orbit when placed in a magnetic field of 5 T.

2+3+2½+2½ **(CO2)**

(OR)

4. *(a)* What do you mean by the vector model of atom?

(b) Briefly explain *j-j* coupling for forming the resultant J.

(c) Calculate the Landé g-factor for $3^2S_{1/2}$ and $3^2P_{3/2}$ levels.

(d) Write down the selection rules governing the transitions between atomic energy levels. 2½+2½+3+2 **(CO2)**

5. *(a)* From quantum mechanical treatment, show that the rotational energy of rigid rotor of a diatomic molecule can be expressed as $\varepsilon_J = BJ(J+1)\ \text{cm}^{-1}$, where B is the rotational constant and J is the rotational quantum number.

(b) For a symmetrical top molecule, show that the energy ε_j for the j^{th} energy level in spectroscopic unit is expressed as $\varepsilon_J = BJ(J+1)+(A-B)\text{K}^2\ \text{cm}^{-1}$, where symbols have the usual meanings.

(c) The $O^{16}H^1$ radical has a moment of inertia $1{\cdot}48\times10^{-40}\ \text{gm-cm}^2$. Calculate its internuclear distance. Hence calculate the angular momentum and angular velocity of the molecule for $J = 5$. Determine the energy absorbed for $J = 4 \leftarrow J = 3$ transition in wavenumber. $(h = 6{\cdot}62\times10^{-27}\ \text{erg-sec})$. 4+2+(2+1+1) **(CO3)**

(OR)

6. *(a)* Briefly describe the effect of isotopic substitution on rotational spectra of diatomic molecules.

(b) What are the effects centrifugal distortion on rotational spectra?

(c) Mention the salient features of Morse potential.

(d) Discuss briefly the construction of He-Ne laser with necessary diagram. 3+2+2+3 **(CO3)**