

2026

PHYSICS — HONOURS

Paper : DSCC-15

(Atomic, Molecular and Laser Physics)

Full Marks : 75

*The figures in the margin indicate full marks.**Candidates are required to give their answers in their own words as far as practicable.*

Symbols and notations have their usual meanings.

Group - A

1. Answer **any five** questions :

- (a) Define Bohr magneton. Calculate the orbital magnetic moment of an electron in a state with orbital quantum number $l = 1$. 1+2
- (b) In Stern-Gerlach experiment, why should one use a beam of neutral atom but not ions? What is the aim of the experiment? 2+1
- (c) Why is it impossible for a state $2^2D_{3/2}$ to exist? 3
- (d) Which of the following molecules are infrared and microwave active : H_2 , NO, HCl? Give proper reasons. 3
- (e) What is meant by metastable state? Why is it important in laser action? Give one example of a metastable state used in lasers. 1+1+1
- (f) Define population inversion. Why is it necessary for laser action? $1\frac{1}{2}+1\frac{1}{2}$
- (g) Explain doppler broadening mechanism in Laser system. 3
- (h) Distinguish between step index fiber and graded index fiber structure. 3

Group - B

Answer **any five** questions.

2. (a) In a Stern-Gerlach experiment, a beam of silver atoms with velocity v enter in an inhomogeneous magnetic field of gradient $\frac{\partial B}{\partial z}$ and length a . Calculate the magnitude of the splitting.

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- (b) The quantum number of two electrons in a two-valence electron atom are $n_1 = 6$, $l_1 = 3$,

$$s_1 = \frac{1}{2}; n_2 = 5, l_2 = 1, s_2 = \frac{1}{2}$$

- (i) Assuming LS coupling, find the possible value of L and hence J.

- (ii) Assuming JJ coupling, find possible values of J.

- (c) Which of these elements H, He and Na exhibits only normal Zeeman effect under external weak magnetic field and why? 5+5+2

3. Consider the transition for ${}^2P_{3/2} \rightarrow {}^2S_{1/2}$ in a weak external magnetic field.

- (a) Find the Lande g factor of each level.
 (b) Write down the number of labels into which each level will split. Draw the diagram to show the splitting.
 (c) Write down the selection rule for ΔM_J . Show the allowed transition in the diagram. (2+2)+(2+2)+(1+2)

4. (a) The transition $3p \rightarrow 3s$ in sodium corresponds to sodium D-line. Due to spin-orbit interaction, the levels split and sodium D-line is found to be two closely spaced lines D1 and D2 of wavelengths 589.6 nm and 589.0 nm respectively. Represent the transition for sodium D1 and D2 lines in an energy level diagram mentioning the spectral term of the states.

- (b) What are non-equivalent electrons? Find the spectral term for an atom with electron configuration $1s^1 2s^1$.

- (c) Find the ground state of nitrogen atom ${}^7N^{14}$ by using Hund's rule. 4+(2+3)+3

5. The Hamiltonian H_{so} for spin-orbit coupling is of the form

$$H_{so} = f(r) \vec{L} \cdot \vec{S}$$

where the symbols have their usual meaning. Show that

$$(i) [\vec{L} \cdot \vec{S}, L^2] = 0$$

$$(ii) [L_z, \vec{L} \cdot \vec{S}] \neq 0$$

$$(iii) [S_z, \vec{L} \cdot \vec{S}] \neq 0$$

$$(iv) \text{ but } [J_z, \vec{L} \cdot \vec{S}] = 0, \text{ where } J_z = L_z + S_z$$

Identify the good quantum numbers in presence of spin-orbit coupling.

2+3+3+2+2

6. (a) Show that for pure rotational spectra the energy eigenvalues for diatomic molecules are $E_J = BJ(J + 1)$, where B is a constant. Show that the levels are equispaced.
- (b) The transition $J = 3$ to $J = 4$ in HCl is associated with radiation of 83.03 cm^{-1} . Calculate the moment of inertia and intermolecular distance of HCl.
- (c) Why are the Stokes lines brighter than Anti-Stokes lines? (3+1)+(3+2)+3
7. (a) Write the expressions for the rates of absorption, spontaneous emission and stimulated emission. What is meant by thermal equilibrium? Hence, derive the Einstein relations between the A and B coefficients.
- (b) Why is optical pumping necessary in laser action? A He-Ne laser emits radiation of wavelength $6328 \text{ \AA}$. Calculate the energy of a photon emitted by the laser. (3+1+4)+(1+3)
8. (a) Explain the role of Ne in He-Ne laser with proper diagram.
- (b) Write the necessary conditions for lasing action. Show that lasing action is not possible in two level laser system.
- (c) The ratio of population of two energy level is 1.059×10^{-30} . Find the wavelength of a laser emitted at 330 K .
- (d) Why does a Ruby laser generate pulsed output? 3+(2+2)+3+2
9. (a) Define numerical aperture of an optical fibre and derive its expression in terms of refractive indices of core and cladding.
- (b) A step-index optical fibre has a core refractive index of 1.48 and cladding refractive index of 1.46. Calculate the acceptance angle of the fibre in air. (3+5)+4
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