

November 2025
M.Sc.
Third Semester
CORE – 10
PHYSICS
Course Code: MPHC 3.21
(Atomic & Molecular Spectroscopy)

Total Mark: 70
Time: 3 hours

Pass Mark: 28

Answer five questions, taking one from each unit.

UNIT-I

1. (a) State and prove the three assumptions of Bohr's atomic model. 8
- (b) Write the expression of energy after the introduction of Sommerfeld's relativistic correction and use it to explain the fine structure of H_α lines. 5
- (c) Why is the first orbit of Sommerfeld's relativistic atom model a circle? 1
2. (a) What necessitated the vector atom model? Describe the important features of vector atom model. Explain the various quantum numbers associated with vector atom model. 1+4+7=12
- (b) For the $^2D_{5/2}$ state of electron, calculate the values of l, s, j , and possible values of m_j . 2

UNIT-II

3. (a) Describe the experimental study of Zeeman effect and explain the classical interpretation of normal Zeeman effect. 11
- (b) How do the energy levels corresponding to state $l=1$ and $l=2$ splits under normal Zeeman effect? Draw the possible spectral lines between the two levels. 3
- 4 (a) Discuss vector atom model of anomalous Zeeman effect. 11

- (b) The calcium line of wavelength $\lambda = 4226.73 \text{ \AA}$ ($P \rightarrow S$) exhibits normal Zeeman splitting when placed in uniform magnetic field of 4 weber/metre². Calculate the wavelength of the three components of normal Zeeman pattern and the separation between them. 3

UNIT-III

5. (a) Apply the variation method to obtain the ground state energy of hydrogen atom. 4
 (b) Describe hydrogen molecule, explaining the wave functions and energies associated with it. 7
 (c) According to the concept of LCAO-MO wave functions, explain why bonding molecular orbital results in lowering of energy, whereas anti-bonding molecular orbital results in increase of energy. 3
- 6 (a) What is Born Oppenheimer approximation? Explain it. 7
 (b) Explain how moment of inertia and bond length of linear triatomic molecule can be determined. 4
 (c) Briefly describe the Raman effect. 3

UNIT-IV

7. (a) What are the salient features of molecular electronic spectra? Describe the formation of electronic spectra in a molecule. 6
 (b) Describe a molecule as a rigid rotator in order to explain pure rotational spectra. 5
 (c) HCl molecule has a rotational constant B value of 1059.3 m^{-1} and a centrifugal distortion constant D of $5.3 \times 10^{-2} \text{ m}^{-1}$. Estimate the vibrational frequency and force constant of the molecule. (Given, mass of proton = $1.67 \times 10^{-27} \text{ kg}$, mass of chlorine = $58.5 \times 10^{-27} \text{ kg}$.) 3
8. (a) Discuss pure rotational Raman spectra. 5
 (b) What is a vibrational spectrum? Describe vibrational spectra of a diatomic molecule. 6
 (c) In HI molecule, the wavenumber difference between the successive lines in the pure rotational spectrum is 12.8 cm^{-1} . If the masses of hydrogen and iodine atoms are respectively 1 g

and 127 g, calculate the moment of inertia and equilibrium bond length. 3

UNIT-V

9. (a) What is nuclear magnetic resonance? Discuss its principle in detail. 5
- (b) Explain how hyperfine structure is obtained in ESR absorption. 6
- (c) State the fundamental principles necessary to understand the basis of the Mössbauer effect. 3
10. (a) Briefly describe nuclear quadrupole resonance (NQR). 4
- (b) In NQR spectroscopy, derive the expression frequency of transition for axially symmetric system. Calculate the frequencies of transition and energies associated with the transition for a nucleus having spin $I = \frac{5}{2}$. Illustrate with energy level diagram. 4+6=10
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