Time : **3 Hrs** Total Marks : 100

N.B. : (1) **All** questions are **compulsory**.

(2) **Figures** to the **right** indicate **full** marks.

(3) Draw **neat** diagrams wherever **necessary**.

(4) Symbols have usual meaning unless otherwise stated.

(5) Use of **non-programmable** calculator is allowed.

1. Attempt any **two:---**

(a) For hydrogen atom, write down the differential equation for the radial part, R(r), of the wave function $\Psi = R(r).\Theta(\theta).\Phi(\phi)$. Using this, show that the magnitude of angular momentum is quantized. **10**

(b) State Pauli's exclusion principle. Show that the system of electrons is described by antisymmetric wave functions. **10**

(c) Discuss Stern-Gerlach experiment, which demonstrates the existence of magnetic moment associated with electron spin. **10**

2 Attempt any **two:---**

(a) Explain with neat diagram, L-S and J-J coupling, for two electron atoms. **10**

(b) What is normal Zeeman effect? Discuss the quantum theory of normal Zeeman effect and obtain an expression for Zeeman shift. **10**

(c) Write expression for average position of electron and explain allowed and forbidden transitions. State selection rules for allowed transitions and discuss whether following transitions are allowed or forbidden. **10**
(i) $\Psi_{200} \rightarrow \psi_{100}$ (ii) $\Psi_{320} \rightarrow \psi_{211}$

3. Attempt any **two:---**

(a) Write expression for vibration-rotation energy of a diatomic molecule. Using appropriate selection rules, find the expression for the frequency of spectral lines in P and R branch of the spectrum. Draw energy level diagram. **10**

(b) Prove that the vibrating diatomic molecule is equivalent to a single particle executing linear harmonic motion. Write quantum expression for its vibrational energy and also draw energy level diagram. **10**

(c) Draw a labeled schematic diagram of a microwave spectrometer and explain function of its various parts. **10**

4. Attempt any **two:---**

(a) Explain pure rotational Raman spectra of a linear diatomic molecule. **10**

(b) What is Raman effect? With the help of neat diagram, describe the experimental set up of Raman effect. **10**

(c) Explain the principle of Electron Spin Resonance (ESR). Describe the ESR spectrometer set up with the help of labeled diagram. **10**

5. Attempt any **four:---**

(i) For a d-electron, draw space quantization diagram. Also calculate cosine of angle between each orientation of $\vec{L}$ and Z-axis. **05**

(ii) Show that the solution $R_{10}(r) = \frac{2}{{a_0}^{3/2}} e^{-r/a_0}$ of radial differential equation of hydrogen atom is normalized. **05**

(iii) Define Lande's 'g' factor and find its value $^2P_{3/2}$ state. **05**

(iv) A spectral line of 4000 A is subjected to 0.5 T of magnetic field. The normal Zeeman shift is observed to be 0.03735 A. Determine the specific charge of an electron (e/m). Given : c = 3 x 10^8 m/s. **05**

(v) Determine rotational energy of J = 2 state in eV for HCl molecule having bondlength 2.1 A. Given : Reduced mass of HCl = 0.162 x 10^{-26}Kg, ħ = 1.054 x 10^{-34}Js, 1eV = 1.6 x 10^{-19} J **05**

(vi) Calculate vibrational frequency of Hydrogen molecule if its force constant is 480 n/m and mass of hydrogen atom is 1.67 x 10^{-27}Kg. **05**

(vii) If bondlength of H_2 is 0.07417nm, what would be the position of the first rotational Raman line in the spectrum? **05**
Given : M(H) = 1.673 x 10^{-27} Kg, h = 6.63 x 10^{-34}Js, c = 3 x 10^8m/s

(viii) The ^{13}C NMR spectrum of a compound occurs at 10.705 MHz in a magnetic field of 1 T. What is its resonance frequency if the applied field is 3 T. **05**

****