$(2\,{}^1/_2$ Hours) **Total Marks: 75**

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

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

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

(5) Symbols have usual meaning unless otherwise stated.

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

List of Constants: change on electron=1.6x10⁻¹⁹C, mass of electron m=9.1x10⁻³¹kg,

Plank's constant h=6.62x10⁻³⁴J.s, velocity of light c=3x10⁸m/s.

1. (a) Attempt any **one:---**

   (i) State Schrodinger's time independent equation in one dimension for linear **10** simple harmonic oscillator. Using appropriate operator solve it to obtain an expression for ground state wave function.

   (ii) Set up steady state Schrodinger's eq. for H-atom in spherical polar **10** co-ordinates. Solve it by the method of separation of variables. Explain how magnetic quantum number m_l arises in solving ϕ equation.

   (b) Attempt any **one:---**

   (i) With neat diagram, explain space quantization of orbital angular **5** momentum for a d-electron in hydrogen atom.

   (ii) Find zero point energy in electron volt of a simple harmonic oscillator with **5** period 0.0005 sec.

2. (a) Attempt any **one:---**

   (i) State Pauli's exclusion principle. Prove that particles obeying Pauli's **10** exclusion principle are described by anti-symmetric wave functions.

   (ii) In case of two electron atoms discuss LS and jj coupling schemes of vector **10** atom model.

   (b) Attempt any **one:---**

   (i) State Hund's rule and explain it in case of $^{57}_{26}$Fe. **5**

   (ii) What are allowed and forbidden transitions? State selection rules for **5** allowed transitions for one electron transitions. Is the transition from Ψ_{320} state to Ψ_{111} state allowed or forbidden?

3. (a) Attempt any **one:---**

   (i) Derive expression for Lande's g-factor and write its definition. **10**

   (ii) What is normal Zeeman effect? Show that normal Zeeman shift is **10**

   $\Delta v = \mp \frac{eB}{4\pi m}$.

   Show the splitting of spectral line, originated due to transition from L= 2 to L= 1, in the presence of an external magnetic field B.

   (b) Attempt any **one:---**

   (i) What is Paschen-Back effect? Explain. State the selection- rules for it.? **5**

   (ii) Show that the Lande's g-factor has a value 1.5 for ³P, ⁵D, ⁷F states. State **5** the condition under which the is valid in general.

4. (a) Attempt any **one:**---
   (i) State Frank –Condon Principle. Using the principle, explain the intensity **10** pattern of electronic bands.
   (ii) What is Raman Effect? Explain it using the polarizability of molecules**. 10**

   (b) Attempt any **one:**---
   (i) State any five observations on Raman Effect. **5**
   (ii) Calculate the moment of inertia and energy of rotational J=2 level in HCl **5** molecule. $M(H)= 1.66\times10^{-27}$ Kg, $M(Cl) = 5.81\times10^{-26}$ kg, bond length = 2.1 A

5. (a) Attempt any **one:**---
   (i) The ground state eigen function of a harmonic oscillator is given by **4** $\Psi_0(y) = Ae^{\frac{-y^2}{2}}$. Obtain eigen function of the first excited state.
   (ii) The ground state wave function of H-atom is **4** $\Psi = \dfrac{e^{-r/a_0}}{a_0^{3/2}\sqrt{\pi}}$ where a_0 is Bohr radius. Show that the most probable value of electron's radial co-ordinate is a_0 itself.

   (b) Attempt any **one:**---
   (i) The wavelength of a spectral line in Hydrogen atom is 6563 A^0. Determine **4** the difference in energy levels involved in the transition.
   (ii) For $^3P_1$ and $^2D_{3/2}$ states find values of S, L, J. **4**

   (c) Attempt any **one:**---
   (i) A spectral line of 4000 A is subject to 0.5 Tesla of magnetic field. The **4** normal Zeeman shift is found to be 0.03735 A. Determine the specific charge of electron (e/m).
   (ii) Draw vector diagrams to represent anomalous Zeeman effect in a) one **4** electron- atom b) Two electron atom obeying L-S coupling.

   (d) Attempt any **one:**---
   (i) In CO molecule, difference in the wave number of consecutive absorption **3** line of rotational spectrum is 3.28×10^2 m^{-1}. Calculate the moment of inertia of CO molecule.
   (ii) The frequency of oscillation of atom in a CO molecule is 3×10^{13}Hz. **3** Calculate force constant. $M(C^{12})= 1.99\times10^{-26}$ kg, $M(O^{16}) =2.66\times10^{-26}$kg.