PG Even Semester Examination, May 2025

PHYSICS

(2nd Semester)

Course No.: PHYCC-553

(Atomic, Molecular and Laser Physics)

Full Marks: 70

Pass Marks: 28

Time: 3 hours

The figures in the right margin indicate full marks for the question.
Answer any five questions selecting one from each unit.

UNIT-I

1. (a) What is the Lamb shift in the hydrogen atom? Describe the exprerimental method used by Lamb and Rutherford to measure the Lamb shift. 1+6=7

   (b) Discuss the quantum mechanical relativistic correction to the hydrogen atom energy levels and its role in fine-structure. 7

2. (a) What is quantum defect in alkali spectra? 2

   (b) Using the Dirac's fine structure formula, calculate the energy difference between the $2^2P_{3/2}$ and $2^2P_{1/2}$ levels in hydrogen. 3

   (c) Prove that the number of terms for 3p3d configuration is the same for LS-coupling as that for jj-coupling. 9

(b) Describe the quantum theory that explain the Raman effect and elaborate on the rotational structure observed in the Raman spectrum of a diatomic molecule. 8

(c) What are the stokes and anti-stokes lines in the Raman spectra? The exciting line in an expreiment is 5460Å and the stokes line is at 5520Å. Find the wavelength of the anti-stokes line. 4

UNIT-V

9. (a) Describe the working principle of a 4-level laser. 6

   (b) Explain the following : 4x2=8

   (i) Spontaneous and stimulated emissions.

   (ii) Population inversion and laser pumping.

10. Write short notes on : 7x2=14

    (i) He-Ne laser

    (ii) Free-electron laser.

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UNIT-II

3. Explain Hartree's SCF method. How the total energy of an atom is calculated by this method? Write its limitations. 14

4. (a) Discus the Zeeman pattern of a line due to $2_{D_{3/2}} \rightarrow 2_{P_{1/2}}$ transition. 7

   (b) Write a note on the breadth of spectral lines. 7

UNIT-III

5. (a) Which of the following molecules will show a mcrowave rotational spectrem and why? 3

   H_2, CH_4, H_2O

   (b) Explain the impact of isotopic substitution on the rotational spectra of a diatomic molecule and illustrate your answer with an example. 6

   (c) The ratio betwen the rotational constant of $^{12}C^{16}O$ and $^{?}C^{16}O$ is found be 1.46. Calculate the atomic mas of $^{?}C$ given the atomic masses of ^{12}C and ^{16}O are 12 amu and 15.994 amu, respectively. Assume that bond length is same in the two molecules. 5

6. (a) What are the P,Q and R branches in the vibrational-rotational spectra? Explain their origin. 6

   (b) Explain why homonuclear diatomic molecules are infrared nactive. 2

   (c) The vibrational-rotational absorption spectrum of HCl shows three absorption frequencies: a strong line at 2886 cm^{-1}, a weaker line at 5668 cm^{-1} and a very weak line at 8347 cm^{-1}. Using this data, 6

   (i) Determine the equilibrium vibrational frequency of the HCl molecule.

   (ii) Calculate its anharmonic constan.

   (iii) Estimate the force constant (k) of the HCL molecule.

   (Assume that HCl behaves as an anharmonic oscillator).

UNIT-IV

7. (a) Explain the origin of rotational fine structure observed in the electronic vibrational spectra of diatomic molecules. 5

   (b) Describe what a Fortrat diagram is and how it is used to analyse such spectra. 3

   (c) Rotational analysis of one-band system is given by 6

   $\nu = 24762 + 25m - 2.1m^2\ cm^{-1}$

   Deduce the position of the band-head, the value of $B_{v'}$ and $B_{V''}$ and the degradations of the band.

8. (a) What are the shortcomings of a classical interpretation of the Raman effect? 2