[122]

SEAT No._____ **No. of Printed Papers: 02**

SARDAR PATEL UNIVERSITY

M.Sc. (Physics) 1st Semester Examination

Wednesday, 24th October, 2018

Subject: PS01CPHY22 (Atomic & Molecular Spectroscopy & Statistical Mechanics)

Time: 10:00 am to 01:00 pm **Total Marks: 70**

Q-1 Eight multiple choice questions. (MCQ) **[01 mark each]**

1) He-Ne laser emits wavelength of _____
   (a) 632.8 nm (b) 632.8 m (c) 632.8 μm (d) 632.8 A°
2) The ratio of the probability of spontaneous to stimulated light emission depends inversely to the _____
   (a) Frequency (b) Wavelength (c) Time (d) None
3) Ionization energy of hydrogen atom in first excited state is
   (a) 3.4 eV (b) 13.6 eV (c) 1.51 eV (d) 13.6 MeV
4) _____ transition is forbidden according to selection rules of electronic transition.
   (a) 2p – 1s (b) 3d-2p (c) 2s-1s (d) All
5) Which of the following spaces is used for the description of a system in quantum statistical mechanics?
   (a) Phase space (b) Euclidean (c) Hilbert space (d) None of these
6) Which of the following condition is satisfied by the degeneracy discriminant in the classical limit?
   (a) $n\lambda^3 \ll 1$ (b) $n\lambda^3 \gg 1$ (c) $(n\lambda)^3 \ll 1$ (d) $(n\lambda)^3 \gg 1$
7) The problem of thermodynamic equilibrium of white dwarf stars can be solved using
   (a) Fermi-Dirac statistics (b) Bose-Einstein statistics
   (c) Maxwell-Boltzmann (d) All of these.
8) Critical temperature (T_C) is a temperature at which
   (a) all the three phases of a substance coexist.
   (b) a substance can undergo a first order phase transition.
   (c) a substance can undergo a second order phase transition.
   (d) a substance melts.

Q-2 Attempt any 7 of the following 9 question briefly. **[02 marks each]**

1. What is Undulator ? Explain briefly with diagram.
2. Why two level systems is not suitable for optical pumping?
3. Explain stimulated Raman effect
4. Write selection rules for electronic transition.
5. Draw a fine structure and hyperfine structure of H-atom.
6. Obtain the density matrix in the canonical ensemble for an electron in the presence of an external magnetic field $\vec{B}$. The intrinsic spin and the magnetic moment of the electron are $\frac{1}{2}\hbar\hat{\sigma}$ and μ_B respectively.
7. How is the fugacity of a gaseous system defined? What are the ranges for the values of fugacity for ideal Bose gas and ideal Fermi gas?
8. What are the criteria for classifying the first and second order phase transitions? Explain using appropriate illustrations.

9. Write the Boltzmann transport equation and explain the physical significance of each term involved in it.

Q-3

(a) Derive equation for minimum pump power required to achieve population inversion for three level laser system. **[06]**

(b) Explain Hyper Raman effect and coherent antistokes Raman scattering. Obtain total polarization for second order induced dipole using classical treatment. **[06]**

OR

(b) Explain three fundamental modes of vibration for Co_2 molecule. Write detailed note on construction and working of Co_2 laser with necessary energy level diagram. **[06]**

Q-4

(a) Derive Thomas-Fermi equation and simplified it by considering two dimensionless variables. **[06]**

(b) Obtain time independent three dimensional Schrödinger equation for Hydrogen atom. **[06]**

OR

(b) What is Lamb shift? Write a detailed note on Lamb and Rutherford experiments. **[06]**

Q-5

(a) Consider an ensemble of N identical system in thermodynamic limit. Starting with the time-dependent Schrodinger equation for the k^{th} system in terms of the wave function $\psi^k(t)$, derive the von Neumann equation which represents the time dependence of density matrix of the ensemble. **[06]**

(b) For a gaseous system composed of molecules with internal motion, describe different components of the partition function associated with internal degrees of freedom. Derive the internal partition function for monatomic molecules with different conditions for the orbital angular momentum (L) and spin angular momentum (S). **[06]**

OR

(b) For an ideal Bose gas system at a given temperature (T) and volume (V), derive the following equation that gives the number of particles (N_e) distributed over the excited states. $\frac{N_e}{V} = \frac{N-N_0}{V} = \frac{1}{\lambda^3}\zeta\left(\frac{3}{2}\right)$, N is the total number of particles in the system, N_0 is the number of particles in the ground state and, λ is the mean thermal wavelength (you are supposed to write its actual expression). $\zeta\left(\frac{3}{2}\right)$ is Reimann zeta function.(i) Explain the circumstances/conditions under which Bose-Einstein condensation (ii) Obtain the condition in terms of T and T_C for fixed N and V. **[06]**

Q-6

(a) Describe the Landau theory of second order phase transition. With the help of appropriate derivations, explain what happens to the entropy and the specific heat of a system on undergoing a second order phase transition. **[06]**

(b) Explain one-dimensional Ising model and derive the expression for the Helmholtz free energy and the magnetization. Explain why one-dimensional Ising model cannot be ferromagnetic. **[06]**

OR

(b) Describe Brownian motion. Explain the formulation of the Langevin equation of motion with proper physical justification for each term. Solve the equation and obtain the expression for the mean square displacement in terms of viscosity of the liquid and the diameter of molecules of the liquid. **[06]**

—X—