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SARDAR PATEL UNIVERSITY
M. Sc. Physics Ist Semester Examination
Monday, Date: 11-04-2016 Time: 10.30 AM to 01.30 PM
CBCS Course No.: PS01CPHY03
Subject: Atomic Molecular & Laser Physics

Note: Symbols have their usual meaning. **Total Marks: 70**

Q.1 Write answers of all eight questions in a table form by showing your choice against the question number. **(8)**

(1) In the case of H-atom "centrifugal barrier potential" varies as _____.
(a) $\frac{1}{r}$ (b) $\frac{1}{r^2}$ (c) $\frac{1}{r^3}$ (d) r^2

(2) For three level laser system, _____ gives necessary mathematical condition for population inversion between level 1 and 2.
(a) $T_{32} = T_{21}$ (b) $T_{32} > T_{21}$ (c) $T_{32} < T_{21}$ (d) $T_{32} > T_{31}$

(3) Most probable decay mechanism of $2S_{½}$ is _____.
(a) non-radiative transition (b) one-photon spontaneous radiation
(c) two-photon emission (d) completely forbidden

(4) Life time for cavity photon in a given lasing system depends on _____.
(a) internal absorption (b) leakage through window (mirror-2)
(c) scattering (d) all of the above

(5) _____ gas is used to increase the efficiency of the CO_2 gas laser.
(a) He (b) N_2 (c) O_2 (d) NH_3

(6) The energy difference between various vibrational levels corresponds to the _____ region
(a) infrared (b) visible (c) ultraviolet (d) far infrared

(7) Angle between HOH in H_2O molecule is more than 90^0, because of_____.
(a) repulsion between electrons (b) stretching effect of rotation
(c) hybridization effect of 2s and 2p orbitals (d) dipolar nature of H_2O

(8) Which of the following does not fall in the microwave region?
(a) ESR (b) hyperfine structure (c) Lamb shift (d) Lyman–α line

Q.2 Answer any seven questions. **(14)**

(1) "Rydberg atoms can be treated as hydrogenic atoms" – why?
(2) Obtain the eigenvalue of *permutation* or *interchange* operator.
(3) With usual notation, prove that for two electron system, $S_z\chi_1(1,2) = \chi_1(1,2)$.
(4) Write two assumptions involved in Thomas-Fermi model for many-electron atom.
(5) Draw a simple diagram showing a few rotational levels for the ground vibrational states in a molecule.
(6) Why normal optical sources do not emit stimulated light?

(7) What are cold atoms?
(8) Give difference between Rayleigh and Raman scattering.
(9) Briefly describe the basic principle of free electron laser.

Q.3 **(a)** For H-atom, setup Hamiltonian and derive $\left[\frac{d^2}{d\rho^2} - \frac{l(l+1)}{\rho^2} + \frac{\lambda}{\rho} - \frac{1}{4}\right] u_{E,l}(\rho) = 0$. **(6)**

Here, $\rho = \left(-\frac{8\mu E}{\hbar^2}\right)^{-\frac{1}{2}} r$ and $\lambda = \frac{Ze^2}{4\pi\epsilon_0 \hbar}\left(-\frac{\mu}{2E}\right)^{-\frac{1}{2}}$ for bound state (E < 0).

(b) Write detailed note on Lamb shift experiment. **(6)**

OR

(b) Write expression for Hamiltonian for two-electron system. Based on the Pauli's exclusion principle, discuss the symmetric and antisymmetric properties of wave function. **(6)**

Q.4 **(a)** Derive $\frac{d^2\chi(x)}{dx^2(x)} - \frac{1}{\sqrt{x}}[\chi(x)]^{\frac{3}{2}} = 0$ using Thomas–Fermi theory for many-electron atoms. Write at least one limitation of the theory. **(6)**

(b) Give detailed note on LCAO method considering an example of H_2^+ ion. **(6)**

OR

(b) Based on Born-Oppenheimer approximation, derive an equation for total energy (E_{s,v_j}) for diatomic molecule. Discuss the use of Morse potential in determining E_{s,v_j}. **(6)**

Q.5 **(a)** Derive necessary equations to show how variation of Laser power around threshold condition take place. **(6)**

(b) For three-level laser system, obtain the condition for population inversion, and derive an expression for threshold pump power. Average pump frequency of a given three-level Ruby laser is 6.25×10^{14}Hz. Density of Cr^{+3} ions and threshold pump rate (W_{pt}) are 1.6×10^{19}cc and 330 s^{-1}. Calculate threshold pump power. **(6)**

OR

(b) Using an expression $\Gamma_{12} = \frac{1}{2\epsilon_0}\frac{\mathcal{D}_{21}^2}{\hbar^2}\int u(\omega)\left\{\frac{\sin[(\omega_{21}-\omega)/2]t}{(\omega_{21}-\omega)/2}\right\}^2 d\omega$ for transition probability and assuming $u(\omega)$ varies slowly, obtain expressions for Einstein coefficients B_{12} and A. **(6)**

Q.6 **(a)** Write detailed note on semiconductor laser. **(6)**

(b) Write the basic principle of laser. Discuss the working of He-Ne laser with the help of suitable diagram. Why only specific dimension of He-Ne discharge tube is selected? **(6)**

OR

(b) Write detailed note on NH_3 maser. **(6)**

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