2025

M.Sc. 3rd Semester Examination

PHYSICS

Paper : PHS - 303

(Molecular Spectroscopy and LASER Physics)

Full Marks : 25 Time : One Hour

The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.

1. Answer any *two* questions : 2×2=4

(a) A Nd : YAG laser emits light corresponding to the transition between the upper laser level E_2=1.38 eV and the lower laser level E_1=1.16 eV. Calculate the energy of the emitted photon in wavenumber (cm^{-1}).

(b) A He-Ne laser operates at a wavelength of $\lambda = 632.8\ nm$. The photon (cavity) lifetime of the resonator is measured to be $\tau_c = 3.2\times10^{-8}$s, determine the quality factor of a laser resonator.

(c) How many revolutions per second does a CO molecule make when J = 3? The CO bond-length and reduced mass of CO are 0.1131 nm and 1.139×10^{-26} kg, respectively.

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(d) The force constant of HCl molecule is 4.8×10^2 N/m. Find the energy required in eV to increase the nuclear seperation by 0.1 nm.

2. Answer any *two* questions : 4×2=8

(a) What do you mean by quality factor of a laser resonator? Derive the expression of quality factor of a laser resonator.

(b) Consider a three-level laser medium (ruby, Cr^{3+} ions) with energy levels 0.00 eV, 1.79 eV, and 3.10 eV. If pumping must excite 10^{23} atoms per cubic meter within 1μs, calculate the required pump power density (W/m^3). Assume one pump photon excites one atom (quantum efficiency = 100%) and neglect other losses.

(c) A molecular system exhibits an electronic transition corresponding to an energy difference of 163.6 cm^{-1}. At equilibrium, a sample contains 2000 molecules in the ground state. Calculate the expected number of molecules in the excited state at temperatures of 77 K, 300 K, and 2500 K.

(d) Assume Diatomic molecule as a non-rigid rotator and anharmonic oscillator. Ignoring the interaction of vibrational and rotational energies find the frequency of transition and hence classify different Branches.

3. Answer any ***one*** question : $8\times1=8$

(a) (i) The observed pure rotational spectrum of carbon monoxide ($^{12}C^{16}O$) exhibits a clear decrease in line spacing with increasing rotational quantum number. Specifically, the $J=0\rightarrow1$ transition appears at 3.845 cm^{-1}, while the spacing between adjacent lines around the $J=5\rightarrow6$ transition is 3.820 cm^{-1}, and this spacing further decreases to 3.770 cm^{-1} near the $J=10\rightarrow11$ transition. From these observations, determine the rotational constants B and moments of inertia I for each case. What explanation can you give for this variation? Reduced mass of CO is 1.139×10^{-26} kg.

(ii) Ignoring rotational energy explain what is meant by progression in an electronic transition and show corresponding transitions from the ground state to a higher state during absorpion. 5+3

(b) (i) Obtain the equation of population inversion in a four-level laser system.

(ii) A four-level laser has a laser transition $E_3\rightarrow E_2$ at wavelength $\lambda=600$ nm. The active center density is $N=2\times10^{25}m^{-3}$. Calculate the energy per photon in electron

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volts. If population inversion requires that 10% of atoms are in the upper laser level E_3, compute the stored energy density U. If pumping occurs in 1 ms, estimate the pump power density. 5+3

Internal Assessment : 5 marks