

Answer TWO questions.

The numbers in square brackets in the right-hand margin indicate the provisional allocation of maximum marks per sub-section of a question.

[Part marks]

1. What is meant by a virtual state in the process of photon absorption by an atom? [2]

Explain the role of virtual states in the following processes

- (a) Two Photon Excitation,
- (b) Multiphoton Ionization,
- (c) Simultaneous Electron Photon Excitation. [6]

Discuss the Two Photon decay process of the $2^2S_{\frac{1}{2}}$ level in atomic hydrogen in relation to the other possible decay modes such as Electric Dipole, Electric Quadrupole and Magnetic Dipole. [6]

Describe an experiment to measure the two photon decay of atomic hydrogen $H(2^2S_{\frac{1}{2}} \rightarrow 1^1S_{\frac{1}{2}})$. [6]

2. Derive an expression for the amplification coefficient for radiation in a two-level medium in terms of the B coefficient. [6]

Why is a population inversion necessary to achieve laser action? [2]

Explain how a population inversion is achieved in an Argon Ion laser. [4]

The ground state of atomic hydrogen $H(1^2S)$ has a Lamb shift. Describe an experiment using Two Photon and Saturation Absorption spectroscopies which enables this shift to be measured. [8]

3. Define the Einstein A and B coefficients. [2]

Consider a two level system in thermodynamic equilibrium and show that

$$c^3 A_{ik} = B_{ik} 8\pi h\nu^3. \quad [5]$$

Estimate the ratio of Spontaneous to Stimulated Emission from a normal tungsten filament light bulb. [3]

Define what is meant by an Optical Oscillator Strength (OOS) or f value. [2]

Given that the A coefficient connecting the non-degenerate states k and i , with energies $E_k > E_i$, is

$$A_{ki} = \left[\frac{e^2 \omega_{ki}^3}{3\pi \epsilon_0 \hbar c^3} \right] |\langle i|r|k \rangle|^2,$$

derive an expression for the OOS connecting states i and k when they have degeneracies g_i and g_k respectively. [6]

If the OOS for the discrete transitions $H(3d \rightarrow np, nf)$ are given by

$$\sum f(3d \rightarrow np) = -0.4 \quad \text{and} \quad \sum f(3d \rightarrow nf) = 1.3$$

then, assuming the Thomas-Kuhn-Reiche sum rule, determine the total OOS associated with these transitions into the continuum. [2]