

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.

Constants:

Boltzmann constant $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$

Planck constant $h = 6.6 \times 10^{-34} \text{ Js}$

Speed of light in vacuum $c = 3.0 \times 10^8 \text{ m s}^{-1}$

- [Part marks]
1. Consider a three-level atom and explain how a Coherent Superposition of atomic states can be produced by a pulsed electron beam. [3]

Derive an expression which shows the Quantum Beat pattern in the emitted radiation of a three level atom. [10]

Describe how Quantum Beats are observed in Beam Foil spectroscopy and briefly describe the apparatus used. [4]

The 3^3P_{012} level of beryllium is studied in a beam foil apparatus with a foil thickness of 100 nm. Given that the separations between the $J=0$ and $J=1$, and $J=1$ and $J=2$ levels are 8114 MHz and 658 MHz respectively, determine the minimum velocity of the beryllium beam such that the states are coherently excited. [3]
 2. How is the Einstein A-coefficient related to the lifetime τ of an atomic state? [1]

Describe an experimental method for measuring the lifetime of a metastable atomic state using a pulsed electron beam. [4]

Discuss the operation of a dye laser noting carefully the role of lifetimes in the pumping sequence [5]

Sketch the optical set up for a transversely pumped dye laser with wavelength selection. [2]

In two-photon ionization of an atom with a laser intensity I the intermediate state can be Real or Virtual. Derive an expression for the transition rate in each case. [6]

Using typical values for the lifetimes of Real and Virtual states, estimate the transition rate in each case.

[2]3.Explain what is meant by Optical Pumping. [2]

Using the $5^2S \rightarrow 5^2P$ transition in Rb, explain how the atoms become orientated using σ^+ light in Zeeman pumping. Neglect the hyperfine structure. [5]

What happens to the magnetization of the rubidium vapour when σ^- light is used? [1]

In atomic Molasses cooling using laser beams the laser light must be chirped. Explain why? [2]

Describe the trapping process in a Zeeman trap. [4]

In Sisyphus cooling a polarization gradient is employed. Explain how this is established and the role of Light Shifts in the cooling process. [6]