UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualification:-

M.Sci.

Physics 4421: Atom and Photon Physics

COURSE CODE	:	**PHYS4421**
UNIT VALUE	:	**0.50**
DATE	:	**06-MAY-05**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

05-C1100-3-30

TURN OVER

Answer any THREE questions

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

Electronic charge: $e = 1.6 \times 10^{-19}$ C

Mass of proton: $m_p = 1.67 \times 10^{-27}$ kg

Planck's constant: $h = 6.63 \times 10^{-34}$ J s

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

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

1. Explain how an electron beam can be used to produce coherent excitation in a three-level system. [4]

   Give the wavefunction which describes a coherent superposition of states $|1\rangle$ and $|2\rangle$. Define all parameters in the wavefunction. [2]

   The natural lifetime of state $|1\rangle$ is 3 ns, and the frequency separation between the states $|1\rangle$ and $|2\rangle$ is 1500 MHz. Determine the maximum lifetime of state $|2\rangle$ in order that quantum beats occur. [2]

   Now take the lifetimes of states $|1\rangle$ and $|2\rangle$ to be equal at 1.5 ns. Determine the design parameters in a beam foil experiment such that quantum beats can be produced and observed. Assume the spatial resolution to be 1 mm. [4]

   Define the coherence length of a light source. [1]

   Explain the terms *correlated* and *non-correlated* events. [1]

   Estimate the coherence length of the radiation emitted by:
   (i) A street lamp.
   (ii) A water filled radiator. [6]

2. Explain what is meant by a virtual state. [2]

Estimate the lifetime of an isolated virtual atomic state in a radiation field of wavelength 532 nm. [3]

A 10 eV electron is elastically scattered through 180° by a helium atom which is at a temperature of 300 K, and is initially moving in a direction orthogonal to the electron's motion. Determine the deflection angle of the helium atom. [4]

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

In Simultaneous Electron-Photon Excitation (SEPE) an electron and photon combine to excite a stationary state.

(i) Draw the Feynman diagrams for all possible first-order processes and explain the associated excitation processes. [4]

(ii) Describe an experiment in which SEPE of He (2^3S_1) can be measured. [3]

3. Briefly outline the origins of fluctuations in a many-atom laser. [3]

Describe the operation of a single atom laser which operates on the Rydberg 63 $^2P_{3/2} \rightarrow$ 61 $^2D_{3/2}$ transition in rubidium at 21.5 GHz. [8]

What properties of Rydberg atoms make them a suitable choice for single atom maser operation? [2]

If the lifetime of Rb (63 $^2P_{3/2}$) is 1 ms and the transit time in the cavity is 30 μs, discuss the interaction of the cavity single mode radiation with the atom. [3]

Discuss the output of the single atom laser using the normalized variance of Poisson statistics. [2]

Determine the number of Rb (63 $^2P_{3/2}$) atoms required to sustain super-Poissonian statistics in the laser. Take the Rabi frequency to be 50 kHz. [2]

4. Explain the physical origin of
(i) natural
(ii) pressure
(iii) Doppler
broadening in a gaseous medium. [3]

Explain the principle of saturation absorption spectroscopy. [6]

Using a pump and probe method, describe an experiment to measure the Lamb shift in the $n = 2$ levels of atomic hydrogen. [9]

What effect does the Lamb shift in the $n = 3$ levels have on this measurement? [2]

5. 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, the wavelength must be chirped. Explain why. [2]

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

A sodium atom (mass 23 u) at 300 K is confined to motion in the z direction and is subjected to optical molasses cooling. The laser beam employed propagates in the z direction and is resonant with the $3\ ^2S_{1/2} \rightarrow 3\ ^2P_{3/2}$ transition at 589 nm.
(i) Calculate the velocity change in a sodium atom for one single photon absorption and emission cycle.
(ii) How far will the atom travel before it is slowed to 100 m s^{-1}? Assume that the laser remains on resonance and that the lifetime of the sodium transition is 15.9 ns. [6]

 END OF PAPER