UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For the following qualifications :-

M.Sci.

Physics 4421: Atom and Photon Physics

COURSE CODE	:	**PHYS4421**
UNIT VALUE	:	**0.50**
DATE	:	**08-MAY-02**
TIME	:	**10.00**
TIME ALLOWED	:	**2 hours 30 minutes**

02-C1097-3-40

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

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

Planck's constant: $h = 6.6 \times 10^{-34}\mathrm{J\ s}$

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

[Part Marks]

1. Given a laser medium in which a population inversion exists, explain the role of the Einstein A and B coefficients in producing laser action. [2]

The absorption of radiation, of intensity I_0, by a medium is described by Beer's Law

$$I = I_o\ e^{-\alpha x}$$

Consider a two level atomic system with energy levels E_1 and E_2. Derive an expression for α, the absorption coefficient in terms of $\Delta E\ (= E_2 - E_1)$, the population difference ΔN and the B coefficient. [8]

How is amplified light produced? [2]

Describe the operation of a dye laser. [5]

Sketch the optical arrangement employed in a transversely pumped dye laser. [3]

2. Explain what is meant by a *dressed* state. [2]

Estimate the lifetime of an isolated dressed atomic state in a radiation field of wavelength 10 μm. [3]

Radiation of wavelength 532 nm is incident on an atom in its ground state which has two dipole allowed levels at 2.00 and 3.00 eV. Determine the lifetime of the dressed state. [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.

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

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

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

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

Derive an expression for the OOS connecting states i and k when each is degenerate. [6]

If the OOS for the discrete transitions H($2p \rightarrow ns$, nd) are given by

$$\sum f(2p \rightarrow ns) = -0.119$$

and

$$\sum f(2p \rightarrow nd) = 0.928$$

then assuming the Thomas-Kuhn-Reiche sum rule determine the total OOS associated with these transitions into the continuum. In the sequence ($2p \rightarrow ns,nd$) which transitions have negative oscillator strengths? [3]

Explain what is meant by molasses cooling. [3]

Describe how cold atoms are held in a Zeeman trap. [6]

4. Explain how two resolved states can be coherently excited using a pulsed electron beam. [4]

What is meant by a coherent superposition of states? [2]

Derive a formula for a model atom which shows the existence of quantum interference in the emitted radiation. [6]

Describe an apparatus in which quantum beats can be observed. [3]

A beam of Be^+ ions atomic mass $9m_p$ of energy 500 keV is incident on a foil. Charge exchange in the foil produces the Be states 3^3P_1 and 3^3P_2 separated by 750 MHz.

1. How many beat oscillations can be observed over 0.01m? [2]
2. What is the minimum foil thickness necessary to produce beat oscillations? Assume the lifetime of each state is 3×10^{-9}s. [3]

5. Define coherence length. [2]

Explain how two events P_1 and P_2, arising from a quasi-monochromatic radiation source, can be correlated or not correlated. [2]

Write down the expression for the First Order Coherence function for two events on the same path separated by time, τ. [2]

Now derive the expression:

$$\gamma(\tau) = (1 - \frac{\tau}{\tau_o})e^{-i\omega\tau}$$

for the degree of self coherence where τ_o is the time between random phase changes and ω is the angular frequency of the radiation. [10]

Derive an expression for the coherence length in terms of the wavelength, λ, of the light source and the bandwidth $\Delta\lambda$. [2]

In a sodium discharge the emissions at 589.5 nm and 588.9 nm are just fully resolved. Calculate the coherence length in each case if the bandwidth is 0.1 nm. [2]

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