Answer 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.

[Part marks]

1. Define Coherence Length

Explain how two evens P_1 and P_2, arising from a quasi monochromatic radiation source can be 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

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

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

Given a discharge lamp line source (λ = 500 nm) with a band width $\Delta\lambda$ = 0.1 nm and a white light source (λ = 500 nm) with a band width $\Delta\lambda$ = 150 nm calculate the coherence length in each case. [2]

Which of the two sources would be the most suitable for use in an interferometer? Explain your choice. [2]

2. Derive the expression

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For the amplification coefficient for radiation of frequency ν_{21} in a two level medium. The symbols in the expression have their usual meanings. [6]

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

Which properties of Rydberg atoms make it a good choice as the medium in a single atom maser? [3]

Using the 63 $P_{3/2}$ – 61 $D_{3/2}$ transition at 21.5 GHz in rubidium, explain the operation of a single atom maser detailing

i. how single atom occupancy of the cavity is produced
ii. the properties of the cavity
iii. how maser operation is demonstrated [7]

Explain quantitatively how the life-time of a single atom in a cavity changes with the cavity frequency.

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

Consider a two level system in thermodynamic equilibrium and show that $c^3 A = B\, 8\pi h\nu^3$. [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

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derive an expression for the OOS connecting states *i* and *k* when they are degenerate. [6]

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

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

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

You may assume the expression

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4. In the interaction of photons with atoms the following processes can take

place:

Ionization
Multiphoton ionization
Above threshold ionization

Explain these terms [3]

Distinguish between resonant and non-resonant two photon ionization of an atom and derive an expression for the transition rates. Discuss clearly the role of intermediate virtual states. [6]

Determine the ‘cross section’ for the resonant and non-resonant cases given that an absorption cross section is 10^{-16} cm^2 and that an ionization cross section is 10^{-19} cm^2; estimating any intermediate atomic life times. [2]

In single photon spectroscopy the Doppler width limits the resolution. Explain how this is removed in two photon absorption spectroscopy. [4]

Describe a method for measuring the two photon absorption spectrum of the $3^2S_{1/2}$-$5^2S_{1/2}$ transition in sodium when the nuclear spin (I = 3/2) is taken into account. [4]

Estimate the residual width of the transitions involved if the lifetime of the $5^2S_{1/2}$ state is 510^{-8}s. [1]

5. Explain the origin and physical significance of the *Phase Shift* in potential scattering.

[3]

Write down the asymptotic boundary condition for the scattering of a plane wave from an atomic target in terms of the scattering amplitude $f(\theta)$. [2]

Derive the formula

Install Equation Editor and double-click here to view equation.

for the elastic scattering of a low energy electron by an atom. [10]

Hence obtain the expression for the differential elastic cross section. [2]

A measured differential elastic cross section at an incident energy of E (a.u.) can be completely described by three phase shifts δ_0, δ_1 and δ_2. Show that the difference in the cross sections at $\theta = 0^o$ and $\theta = 90^o$ in terms of E, δ_1 and δ_2 is given by [3]

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You may ASSUME the asymptotic formulae

Install Equation Editor and double-click here to view equation.