NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4102 LASERS AND MODERN OPTICS

SUPPLEMENTARY EXAMIANTIONS

BSc HONOURS PART IV : MAY 2001 DURATION : 3 HOURS

ANSWER ALL PARTS OF QUESTION 1 IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS

SECTION A

1 (a) Find the expression for the gain coefficient at the centre of the Loretzian profile in terms of Einstein A coefficient and the population inversion. [6]

(b) Show that the power spectrum of a damped oscillation which is driven by a harmonic force is given by a Lorenztian profile function. [6]

(c) A certain commercial Helium/Neon laser is advertised to have a far-field divergence angle of 1 milli-radian at $\lambda = 6328$Å. What is a beam waist (w_o) of this beam? [10]

(d) A laser has two concarve mirrors that are 0.8m apart. One has a radius of curvature of 0.1m the other of 1.5m.
Is the resonator stable? Show this from the stability condition. [6]

(e) Consider a transition at 5000 Å with a width of 1Å and a cavity $2cm^3$ in volume.

(i) Convert this wavelength interval (1Å) to frequency units in GHz. [3]

(ii) How many electromagnetic modes exist in this frequency band for this cavity? [3]

(g) (i) Explain what causes spontaneous emission. [3]

(iii) Explain the role of spontaneous emission in laser oscillation. [3]

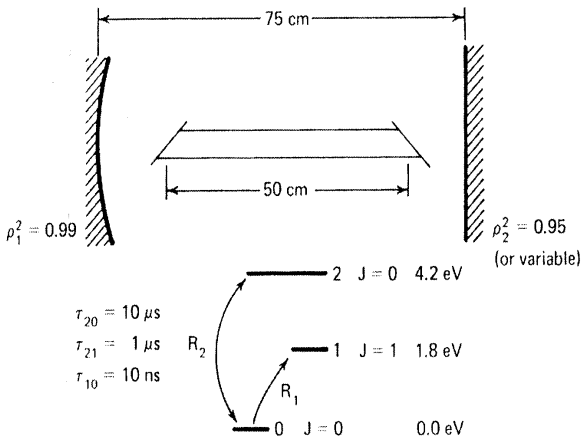
SECTION B

2. (a) Given a two-level atomic medium whose atoms have no distinguishing feature how would you set about finding the gain coefficient assuming that you can create a population inversion and that you can provide feedback. [10]

(b) Sketch the gain coefficient as a function of the frequency ν given that $\nu_{21} = (E_2 - E_1)/h$ for the medium. [6]

(c) Relate the gain coefficient to the power gain for this medium. [4]

3. Consider the hypothetical laser system with energy – level configuration as shown below.



ρ_1^2 and ρ_2^2 are the power reflectivities of the respective mirrors.

(a) If we neglect all other processes except radiation, what is the branching ratio for the transition 2 $\rightarrow$1? [4]

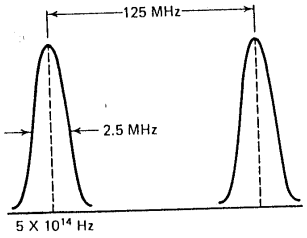
(b) What is the quantum efficiency of this laser? [3]

(c) If the mass of the atom is 133amu and the gas temperature is 125°C find the Doppler width of the transition 2 $\rightarrow$ 1. [3]

(d) Find the natural line width of the transition, 2 $\rightarrow$ 1. [5]

(e) What is the threshold gain coefficient? [5]

4 The diagram below shows the cavity modes of a laser resonator with the centre line as indicated.



(a) What is the length of the cavity? [4]

(b) What is the Finesse? [4]

(c) What is the Q of the cavity? [4]

(d) What is the photon lifetime? [4]

(e) What is the mode number at the centre frequency? [4]

5. Given a 1 - W TEMo,o beam of $\lambda = 514.5$nm from an argon - ion laser with a minimum spot size (waist) of 2 mm located at $Z = 0$.

(a) How far will this beam propagate before the spot size is 10 mm? [5]

(b) What is the radius of curvature of the phase front at this distance ? [5]

(c) What is the amplitude of the electric field at $r = 0$. [5]

(d) Make a labelled sketch of a Gaussian laser beam showing the intensity distribution. [5]

6. (a) Discuss how amplified spontaneous emission might limit the amount of energy that can be stored in the population inversion of an amplifier. [5]

(b) Discuss the following laser characteristics

(i) directivity [3]

(ii) monochromaticity [3]

(iii) high power density [3]

(c) Give two applications of any one of the characteristics that you have discussed in (b). [6]

END OF PAPER