TECHNICAL UNIVERSITY OF MOMBASA

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MEDICAL ENGINEERING

UNIVERSITY EXAMINATION FOR:

BACHELOR OF SCIENCE IN MEDICAL ENGINEERING

ECL 4404: MEDICAL OPTICS II.

END OF SEMESTER EXAMINATION

SERIES: AUGUST, 2024

TIME: 2 HOURS

DATE: AUGUST, 2024

Instructions to Candidates

You should have the following for this examination

-Answer Booklet, examination pass and student ID

This paper consists of FIVE questions. Answer question ONE and any other TWO

The table of physical constants and properties is provided at the end of the paper.

Do not write on the question paper.

Question ONE

(a) Discuss any THREE properties of laser light. **(8 marks)**

(b) Derive an expression for the frequency of released photon due to an induced transition from level 2 to level 1 for a two-energy level laser system. **(13 marks)**

(c) Show that for normal optical source ($T = 10^3$ K, $\lambda = 6000$Å) emission is incoherent. **(6 marks)**

(d) State THREE advantages of laser over other optical sources. **(3 marks)**

Question TWO

(a) Discuss the theory of population inversion. Illustrate your discussion with energy level diagram of common non-semiconductor lasers. **(9 marks)**

(b) Describe qualitatively the operation of Helium-Neon laser with a rough energy diagram of relevant atoms involved **(11 marks)**

Question THREE

(a) The practical realization of the laser is an optical oscillator. The operation of the device may be described by the formation of an electromagnetic standing wave.

(i) State the Schrodinger's wave equation
(ii) Show that a bound particle is represented by a standing wave
(iii) Calculate the first THREE energy levels of an electron in an infinite potential well of width 5 Å **(13.5 marks)**

(b) (i) Describe Q-switching
(ii) State and explain the TWO important requirements for Q-switching.
(iii) Calculate the energy of output pulses of Q-switched laser whose parameters are given as $N_i = 10^{24} m^{-3}$ laser frequency $=5x10^{14}$Hz. volume= $10^{-5} m^3$. Assume that $N_f << N_i$. **(6.5 marks)**

Question FOUR

(a) Describe Holography **(11.5 marks)**

(b) State and describe TWO major applications of holography in the medical field. **(4.5 marks)**

(c) State any FOUR applications of quantum mechanics. **(4 marks)**.

Question FOUR

(a) State THREE methods of producing population inversion and the corresponding lasers generated. **(6 marks)**

(b) Calculate the relative population of a two-energy level system such that a transition from the higher to the lower energy level will give visible radiations of 550 nm, T = 300 K and that $g_1 = g_2$ **(6.5 marks)**

(c) State THREE reasons as to why the laser fulfils the major requirements for optical fiber emitter. **(3 marks)**

(d) A double hetero-structure Fabry-perot edge emitting laser in the ALGaAs-GaAs system emits in the neighborhood of 900nm. The chip is 300 μm long. Determine the wavelength difference between two adjacent modes. **(4.5 marks)**

Question FIVE

(a) Discuss laser classification and safety. **(9 marks)**

(b) A 10 mW He-Ne laser has efficiency of 1%. Assume that all input energy is utilized in pumping the atoms from the ground state to the excited state which is 20 eV above the ground. Determine the number of atoms that can be promoted to the excited state in one second. **(2.5 marks)**

(c) Calculate the number of modes present in the wavelength range of 2nm centered about 500nm. Given the length of the optical resonator is 30 cm. **(2 marks)**

(d) Discuss mode locking in lasers. **(6.5 marks)**

PHYSICAL CONSTANTS

Permittivity of free space	$8.854X10^{-12}F/M$
Permeability of free space	$4\pi x10^{-7}H/M$
Electron charge	$1.602x10^{-19}C$
Electron rest mass	$9.108x10^{-31}kg$
Electron charge/mass ratio	$1.759X10^{-11}$ C/kg
Photon rest mass	1836m
Planck's constant	$6.625x10^{-34}$ Js
Boltzmann's constant	$1.38x10^{-23}J/K$
Speed of light	$3X10^{8}$ ms^{-1}
kT at room temperature	0.0259 eV

Properties of some common semiconductors at room temperature (300K)

	Silicon	Germanium
Relative permittivity, ε_r	11.8	16
Energy gap, E eV	1.08	0.66
Electron mobility, μ_e m^2/Vs	0.13	0.38
Hole mobility, μ_h m^2/Vs	0.05	0.18
Instrinsic concentration, n_i m^{-3}	$1.4x10^{16}$	$2.5x10^{19}$
Density of state at CB,N_c, m^{-3}	$2.8x10^{25}$	$1x10^{25}$
Density of state at VB,N_V m^{-3}	$1x10^{25}$	$1.4x10^{24}$
Effective electron mass, m_{c*}	1.1m	0.55m
Effective hole mass, m_h^*	0.56m	0.37m