PAPER 2

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.

SPECIAL/ SUPPLEMENTARY EXAMINATION

SERIES: JULY, 2025

TIME: 2 HOURS

DATE: JULY, 2025

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

Do not write on the question paper.

Question ONE

(a) Discuss the essential requirements for the construction of a laser. **(10 marks)**

(b) A 3mW laser beam of wavelength $\lambda = 6x10^{-5}$is focused by a convex lens. The focal length of the lens is 5 cm and radius of the circular aperture is 1cm.

(i) Find the intensity of the focused spot.

(ii) If the coherence time of the laser is 50ns, find the monochromacity of the source. **(7 marks)**

(c) Describe qualitatively how a He-Ne laser works. **(13 marks)**

Question TWO

(a) Distinguish between temporal and spatial coherence**.** **(3 marks)**

(b) Describe metastable states. Give examples **(3 marks)**

(c) Calculate the gain constant α_{12} of a laser beam from the following data N_2 - $N_1 = 5x10^{16}\ cm^{-3}$, λ_o=65000 Å, line-width λ=15Å and the lifetime for spontaneous emission $=2x10^{-4.}$ s **(7 marks)**

(d) Using an energy level diagram describe the principle of operation of Nd:YAG laser. **(7 marks)**

Question THREE

(a) Describe qualitatively of operation of carbon diode laser with the aid of energy band diagrams.

(15 marks)

(b) Calculate the ratio of stimulated to spontaneous emission rate at a temperature of 250° for sodium D lines. **(5 marks)**

Question FOUR

(a) Explain the concept of negative temperature in connection with the operation of a laser.

(3 marks)

(b) (i) By considering the rate equations for a three level laser, derive an expression for the threshold population inversion in terms of the laser parameters. Hence compare the pump power required to bring a three level and four level laser to threshold.

(ii) Calculate the threshold pumping power for an Nd: glass laser, given that the critical population inversion is $9x10^{21}m^{-3}$, the spontaneous lifetime is 300 μs and that the upper laser level is at an energy of 1.4 eV. **(10 marks)**

(c) Discuss the application of lasers in medical field**.** **(5 marks)**

(d) Explain high monochromacity and high directionality of laser radiation**.** **(2 marks)**

Question FIVE

(a) Compare the ideal light output against current characteristics for the injection laser with one from a more typical device. Discuss the major points on the characteristics and indicate why the two differ. **(5marks)**

(b) For 2p----------1s transition in hydrogen atom, the mean spontaneous lifetime is $1.66x10^{-8}$sec. and the frequency of emitted radiation is $2.4x10^{15}$ Hz. Calculate the probability of stimulated emission **(3.5 marks)**

(c) With the help of energy level diagrams discuss the liquid dye lasers. **(11.5 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