PAPER 1

TECHNICAL UNIVERSITY OF MOMBASA

SCHOOL OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF ELECTRICAL & ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATION FOR:

DIPLOMA IN ELECTRICAL & ELECTRONIC ENGINEERING (CONTROL AND INSTRUMENTATION)

ECI 2307: OPTICAL INSTRUMENTATION

END OF SEMESTER EXAMINATION

SERIES: APRIL, 2025

TIME: 2 HOURS

DATE: APRIL, 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. Attempt QUESTION ONE and any other TWO QUESTIONS

Do not write on the question paper.

Question ONE (Compulsory)

(a) Define the following terms as applied to optical fibers

(i) Acceptance angle

(ii) Numerical Aperture

(iii) Meridional ray

(iv) Skew rays. **(4 marks)**

(b) A silica optical fiber with a core diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and a cladding refractive index of 1.47. Determine:

(i) The critical angle at the core-cladding interface.

(ii) The NA for the fiber

(iii) The acceptance angle in air for the fiber. **(5 marks)**

(c) (i) Define optical metrology

(ii) Describe interferometry

(iii) Using relevant diagrams, describe the principle of operation optical strain sensor. **(10.5 marks)**

(d) Using relevant diagrams differentiate between spontaneous emission and stimulated emission. **(10.5 marks)**

Question THREE

(a) Consider a solar cell

(i) Define it

(ii) With the aid of relevant diagrams, discuss the principle of operation of a solar cell.

(iii) State ONE material that is used in construction of solar cells and the criteria for materials to be used**.** **(12.5 marks)**

(b) Discuss laser classification and safety. **(7.5 marks)**

Question TWO

(a) Develop the theory of population inversion. Illustrate your answer with energy level diagram of common nonsemiconductor lasers. **(17 marks)**

(b) A ruby laser contains a crystal length 4 cm with a refractive index of 1.78. The peak emission wavelength from the device is 0.55µm. Determine the number of longitudinal modes and their frequency separation. **(3 marks)**

Question FOUR

(a) (i) Define photo-detection

(ii) State THREE properties of photodetectors. (**4 marks)**

(b) (i) Define the following terms as applied to photodiodes: quantum efficiency and responsivity

(c) When $3x10^{11}$ photons each with a wavelength of 0.85 µm are incident on a photo-diode , on average $1.2x10^{11}$ electrons are collected at the terminals of the device. Determine the quantum efficiency and responsivity of the photodiode at 0.85 µm. **(5 marks)**

(d) (i) Using relevant diagrams differentiate between optical step index fiber and graded index fiber.

(ii**)** State THREE advantages of step index fibers over graded index fibers. **(11 marks)**

Question FIVE

(a) (i) Define a semiconductor optical amplifier

(ii) Draw the general block diagram of optical amplification

(iii) Discuss the principle of operation of optical amplifier

(v) Name ONE example of optical amplifier. **(8.5 marks)**

(b) State TWO advantages of optical fiber communication. **(2 marks)**

Using relevant diagrams discuss the ruby laser. **(9.5 marks)**

(c)

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