# TECHNICAL UNIVERSITY OF MOMBASA

FACULTY OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF ELECTRICAL & ELECTRONIC ENGINEERING

## SUPPLEMENTARY UNIVERSITY EXAMINATION FOR:

BACHELOR OF SCIENCE IN ELECTRICAL & ELECTRONIC ENGINEERING

EEE2504: QUANTUM ELECTRONICS

SPECIAL/SUPPLEMENTARY EXAMINATION

**SERIES:** SEPTEMBER, 2018

**TIME:** 2 HOURS

**DATE:** SEPTEMBER, 2018

**Instructions to Candidates**

You should have the following for this examination

*-Answer Booklet, examination pass and student ID*

1.This paper consists of FIVE questions. Attempt QUESTION ONE and any other TWO QUESTIONS

2. Physical constants and properties are provided at the end of the paper.

**Do not write on the question paper.**

**Question ONE (Compulsory)**

(a) (i) Briefly outline any THREE general requirements for a source in optical fiber communications.

(ii) Discuss THREE areas in which the injection laser fulfils these requirements.

(iii) Comment on any drawbacks of using the injection laser as an optical fiber communication device. **(10 marks)**

(b) (i) Define the relative index difference for an optical fiber.

(ii) Show how the relative index difference is related to the numerical aperture.

(iii) The velocity of light in the core of a step index is $2.01 \times 10^8$ $ms^{-1}$, and the critical angle at the core-cladding interface is $80^0$.Determine the numerical aperture and

the acceptance angle for the fiber in air, assuming it has a core diameter suitable for consideration by ray analysis. The velocity of light in a vacuum is $2.998 \times 10^8$.

**(10 marks)**

(c) (i) Discuss the operation of the silicon RAPD, describing how it differs from the p-n photodiode

(ii) Outline the advantage and drawbacks with the use of the RAPD as a detector for optical fiber communications

(iii) When 800photons per second are incident on a p-i-n photo-diode operating a wavelength of 1.3μm they generate an average 550 electrons per second which are collected. Calculate the responsivity of the device. **(10 marks)**

**Question TWO**

(a) (i) Describe the technique used to give both electrical and optical confinement in multimode injection lasers.

(ii) Calculate the ratio of the stimulated emission rate to the spontaneous emission rate for an incandescent lamp operating at a temperature of 1000K. It may be assumed that the average operating wavelength of 0.5μm. **(10 marks)**

(b) (i) Explain the term solid-state laser

(ii) With the aid of a well labeled diagram briefly explain the design structure and operation of a Ruby laser. **(10 marks)**

**Question THREE**

(a) (i) Describe the phenomena of modal noise in optical fibers and suggest how it may be avoided.

(ii) The mean optical power launched into an optical fiber link is 1.5mW and the fiber has an attenuation of 0.5 $dBkm^{-1}$.Determine the maximum possible link length without repeaters (assuming lossless connectors) when the maximum mean optical power level required at the detector is 2μW.

**(4 marks)**

(b) In single mode fibers, the total dispersion is composed of three components. State and explain these components.

**(6 marks)**

(c) Estimate the critical radius of curvature at which large bending losses occur in each of the two step index fibers with the following parameters:

(i) A multimode fiber with a core refractive index of 1.5, a relative refractive index difference of 3% and an operating wavelength of 0.82 μm.

(ii) An 8μm core diameter single-mode fiber with a core refractive index the same as (i), a relative refractive index difference of 0.3% and operating wavelength of 1.55μm.

**(10 marks)**

**Question FOUR**

(a) Using Bohr atomic model derive expression for the velocity and radius of an electron spinning in its orbit.

**(10 marks)**

(b) A p-i-n photodiode on average generates one electron-hole pair per three incident photons at a wavelength of 0.8 μm. assuming all the electrons are collected calculate:

(i) The quantum efficiency of the device.

(ii) Its maximum possible band-gap energy

(iii) The mean output photocurrent when the received optical power is $10^{-7}$ W

**(6 marks)**

c) Explain the detection process in the p-n photodiode. Compare this device with the p-i-n photodiode.

**(4 marks)**

**Question FIVE**

(a) With the aid of a well labeled diagram explain the functions of the main components of a laser system. ` **(7 marks)**

(b) (i) State THREE main functions of cladding of an optical fiber.

(ii) 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.

**(8 marks)**

(c) When the mean optical power launched into an 8km length of fiber is 120 μW, the mean optical power at the fiber output is 3 μW. Determine :

(i) The overall signal attenuation in decibels, through the fiber assuming there are no connectors or splicers.

(ii) The signal attenuation per kilometer for the fiber.

(iii) The overall signal attenuation for a 10 km optical link using the same fiber with splices at 1km intervals, each giving an attenuation of 1 dB.

(iv) The numerical input/output power ratio in (iii). **(5 marks)**