



MACHAKOS UNIVERSITY

University Examinations for 2020/2021

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION
TECHNOLOGY)

SPH 437: OPTICAL COMMUNICATION SYSTEMS

DATE: 9/8/2021

TIME: 8:30 – 10:30 AM

INSTRUCTIONS:

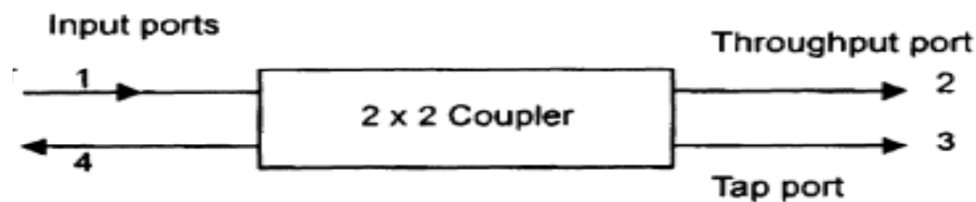
QUESTION ONE (COMPULSORY) (30 MARKS)

- i) Answer question one and any other two questions
 - ii) You are provided with table of physical constants
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- a) Explain the implication of the following terms to optoelectronics (6 marks)
 - i. Absorption
 - ii. Band-gap
 - iii. Emission
 - b) Given that the radiative lifetime $\tau_r = 10^9/N$ s, where N is the semiconductor doping in cm^{-3} and the non-radiative lifetime τ_{nr} is equal to 10^{-7} s. Find the cutoff frequency of an LED having a doping of 10^{19} cm^{-3} . (4 marks)
 - c) Describe using appropriate illustration how a photodetector converts light signal into electrical signal. Include the PN junction operation (8 marks)

- d) Using appropriate energy diagram, explain the types of band gap, their implication on various uses. Give example of application citing the reason for the type of application (6 marks)
- e) The radiative and non radiative recombination life times of minority carriers in the active region of a double heterojunction LED are 60 nsec and 90 nsec respectively and the peak emission wavelength of Silicon is 870 nm and the drive current is 40 mA. (6 marks)
- Determine the total carrier recombination life time
 - optical power generated internally

QUESTION TWO (20 MARKS)

- a) A particular type of optical fibre demonstrated a loss of 40% in a length of 7km. In a 35km link using this type of fibre the required output power is $0.2\mu\text{W}$. Determine the minimum possible launched power assuming no joint losses, margin and penalties. (7 marks)
- b) Calculate the output power at each port in the coupler shown if the excess loss is 2dB, Directionality loss is -50dB and a splitting ratio of 4:1. The input power is $40\mu\text{W}$ (7 marks)



- c) A step-index fiber has a core index of refraction of 1.425. The cut-off angle for light entering the fiber from air is found to be 8.50° . Determine (6 marks)
- the numerical aperture of the fiber
 - the index of refraction of the cladding of this fiber
 - the new numerical aperture and cut-off angle if the fiber were submersed in water

QUESTION THREE 20 MARKS

- a) Explain 3 sources of noise and disturbances in optical devices (6 marks)
- b) Explain four advantages and four disadvantages of LED (8 marks)
- c) Explain condition necessary to sustain lasing (6 marks)

QUESTION FOUR 20 MARKS

- a) Explain four parameter used in measurement of performance of a photodiode used as a receiver (8 marks)
- b) The following parameters were chosen for a long haul single mode optical fiber system operating at $1.3\mu\text{m}$. (8 marks)
- Mean power launched from laser = 3dBm
 - Cabled fiber loss = 0.4 dB/km
 - Splice loss = 0.1 dB/km
 - Connector loss at transmitter and receiver = 1 dB each
 - Mean power required at the APD
 - a) When operating at 35Mbps(BER = 10^{-9}) -55 dBm
 - b) When operating at 400Mbps(BER = 10^{-9}) -44 dBm
 - Required safety margin = +7 dB

Determine:

- i. Maximum possible link length without repeaters when operating at 35Mbps. It may be assumed that there is no dispersion-equalization penalty at this rate.
 - ii. Maximum possible link length without repeaters when operating at 400Mbps.
 - iii. The reduction in the maximum possible link length without repeaters of (ii) when there is dispersion-equalization penalty of 1.5dB.
- c) An electron of a hydrogen atom falls from the M (12.1 eV) to the L (10.2 eV) shell. Determine the wavelength of the radiated light (4 marks)

QUESTION FIVE (20 MARKS)

- a) Derive the following expression for LED (10 marks)
- i) internal quantum efficiency
 - ii) internally generated optical power
 - iii) external efficiency
- b) Explain five losses in an LED. Show the appropriate relations used to calculate the respective efficiencies (10 marks)

Physical Constants

Avogadro's number	$N_A = 6.02 \times 10^{+23}$ atoms per gram molecular weight
Boltzmann's constant	$k = 1.38 \times 10^{-23} \text{ J/K}$ $= 8.62 \times 10^{-5} \text{ eV/K}$
Electronic charge (magnitude)	$e = 1.60 \times 10^{-19} \text{ C}$
Free electron rest mass	$m_0 = 9.11 \times 10^{-31} \text{ kg}$
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$
Permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-14} \text{ F/cm}$ $= 8.85 \times 10^{-12} \text{ F/m}$
Planck's constant	$h = 6.625 \times 10^{-34} \text{ J-s}$ $= 4.135 \times 10^{-15} \text{ eV-s}$ $\frac{h}{2\pi} = \hbar = 1.054 \times 10^{-34} \text{ J-s}$
Proton rest mass	$M = 1.67 \times 10^{-27} \text{ kg}$
Speed of light in vacuum	$c = 2.998 \times 10^{10} \text{ cm/s}$
Thermal voltage ($T = 300 \text{ K}$)	$V_t = \frac{kT}{e} = 0.0259 \text{ V}$ $kT = 0.0259 \text{ eV}$

Material	Index of Refraction (n)
Vacuum	1.000
Air	1.000277
Water	1.333333
Ice	1.31
Glass	About 1.5
Diamond	2.417