Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	FIBER OPTIC TECHNOLOGY
COURSE CODE	:	BNF 43103
PROGRAMME CODE	:	BNF
EXAMINATION DATE	:	JULY / AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTION	1.	ANSWER **ALL** QUESTIONS
	2.	THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK**
	3.	STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 (a) Optical signal attenuates when propagating in optical fibers. Examine the spectral loss profile of a single mode optical fiber in **Figure Q1(a)**.

(i) Explain why wavelength 1550 nm and 1310 nm are usually being used in optical transmission system.

(2 marks)

(ii) Determine the main cause of the high attenuation at 1380 nm.

(1 mark)

(iii) Explain **THREE (3)** attenuation mechanisms in optical fiber.

(5 marks)

(b) By using Snell's law and geometry skills, determine the exit angle θ of the ray relative to the horizontal after having passed through the prism in **Figure Q1(b)**.

(7 marks)

(c) Differentiate between a multimode step index fiber and a single-mode step index fiber. Then, with the aid of a simple ray diagram, describe how an optical signal propagates inside these two types of fiber.

(4 marks)

(d) Consider a piece of step-index optical fiber with a refractive index at the fiber core and cladding of 1.48 and 1.46, respectively. Calculate:

(i) Numerical aperture
(ii) Diameter of the fiber core if this fiber is designed to be single-mode for wavelength starting from 1100 nm? Assume $V \approx 2.405$.
(iii) Number of modes if the fiber is used for 850 nm laser.

(6 marks)

Q2 (a) Explain the concept of the following terms with the aid of suitable diagram:

(i) Absorption
(ii) Stimulated emission
(iii) Spontaneous emission

(6 marks)

(b) Optical transmission light sources, for example, light-emitting diode (LED) and laser convert electrical signal to a light wave.

(i) Describe the operating principle of LED and laser.

(4 marks)

(ii) Sketch the typical output power spectrum of LED and laser. For laser, illustrate the output spectrum when operating below and after threshold current.

(6 marks)

(c) List and describe **TWO (2)** primary characteristics of light detectors.

(2 marks)

(d) Discuss on how temperature can change silicon PIN photodiode noise.

(2 marks)

(e) The C and L spectral bands cover a wavelength range from 1530 to 1610 nm.

(i) Identify on how many channels can be transmitted through WDM when the channel spacing is 25 GHz.

(2 marks)

(ii) Determine the effective bit rate–distance product when a WDM signal covering the two bands using 10-Gb/s channels is transmitted over 2000 km.

(3 marks)

Q3 (a) You are required to characterize a biconical-tapered coupler of unknown specification as shown in Figure Q3(a). The power injected from the laser source into the coupler is 200 μW. The measured output power shows a reading of 90 μW, 85 μW and 6.3 nW for P_2, P_3 and P_4, respectively. Determine the:

(i) Coupling ratio
(ii) Insertion loss
(iii) Excess loss
(iv) Directivity

(8 marks)

(b) A 128×128 broadcast star is made by using 2×2 directional couplers, each having an insertion loss of 0.2 dB. Each channel transmits 1 mW of average power and requires 1 μW of average received power for operation at 1 Gb/s. Calculate the maximum transmission distance for each channel. Assume a cable loss of 0.25 dB/km and a loss of 3 dB from connectors and splices.

(5 marks)

(c) An optical isolator allows the flow of optical signal power in only one direction. Propose a device which is made of isolators and follows a closed loop path.

(2 marks)

(d) Erbium-doped fiber amplifier (EDFA) and laser use stimulated emission to operate.

(i) Draw a block diagram of a basic EDFA and explain the function of every component of the basic EDFA.

(5 marks)

(ii) The EDFA can be extended to become a fiber laser. Suggest **TWO (2)** ways to modify the EDFA to become an erbium-doped fiber laser (EDFL). Also, state the **ONE (1)** main difference between laser and EDFA.

(5 marks)

Q4 (a) UniFi is a broadband service by Telekom Malaysia (TM) that uses fiber optics to deliver high speed internet, phone and internet protocol TV (IPTV) services to customers' homes. From your understanding, illustrate the network from the central office to the in-home networks. Specify the type of lasers, fibers, number of users and the technology that suitable to describe UniFi systems.

(10 marks)

(b) Laser diode with an input power of 0.5 mW is launched into a fiber. The launch amplifier has a gain of 25 dB; the following fiber has a length of 100 km and a loss of 0.25 dB/km. This is followed by an inline amplifier having sufficient gain to bring the power level back same as the output power of launching amplifier. The following fiber has the same attenuation with 150 km of length. A preamplifier next boosts the power level of 0.5 mW.

(i) Draw the block diagram of the system.

(3 marks)

(ii) Compute the gain of the preamplifier.

(8 marks)

(iii) Plot the signal power level (in dBm) as a function of position along the fiber system.

(4 marks)

-END OF QUESTIONS –

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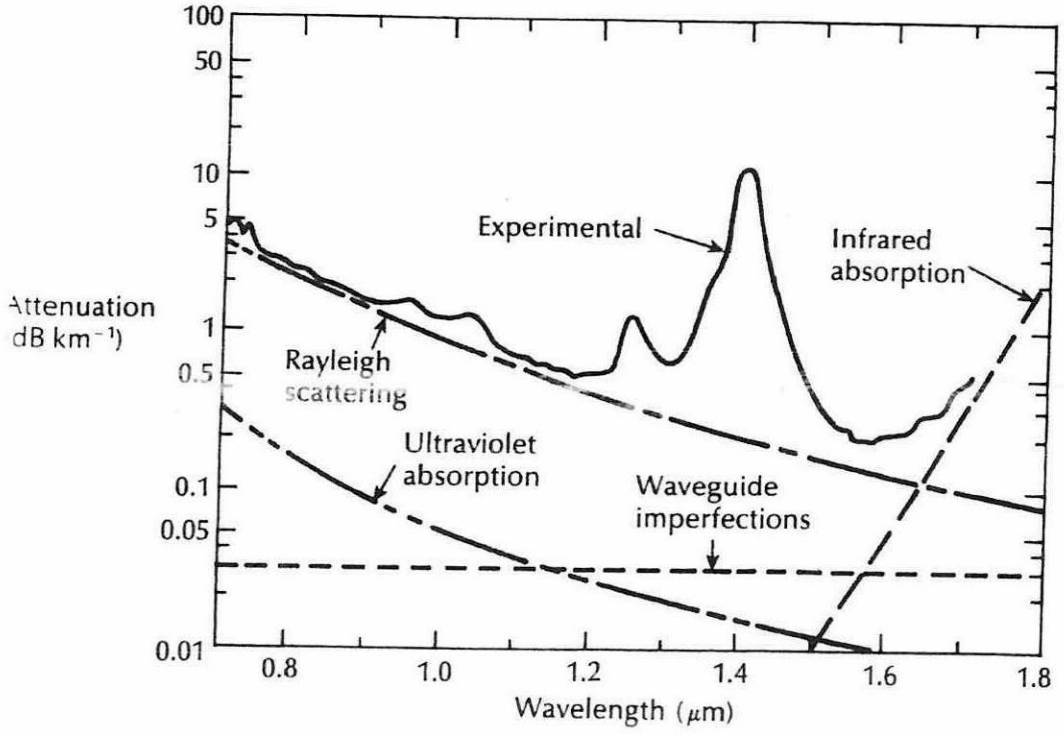
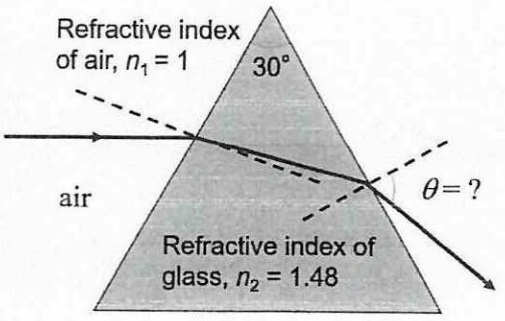


Figure Q1(a)



The triangle is isosceles.
Incident ray is horizontal, parallel to the base.

Figure Q1(b)

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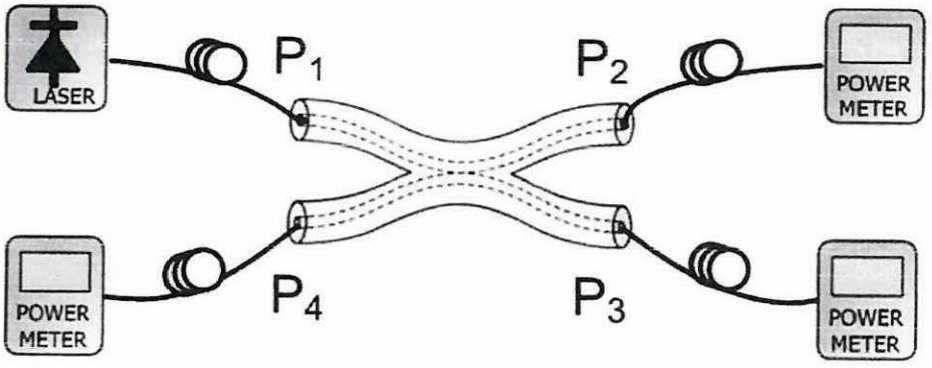

Figure Q3(a)

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Table 1: Formula

Speed of light $c = 3 \times 10^8$ m/s Refractive index $n = c / v$ $n = \lambda_0 / \lambda$ Snell's law $n_i \sin\theta_i = n_r \sin\theta_r$ Critical angle $\theta_c = \sin^{-1}(n_r/n_i)$ Plain wave velocity $v = \frac{\omega}{k_1} = \frac{c}{n_1}$ Group velocity $V_g = \frac{d\omega}{d\beta}$ Group delay $\tau_g = \frac{l}{V_g} = l\frac{d\beta}{d\omega}$	Numerical Aperture (NA) $NA = n_0 \sin\alpha = \sqrt{n_1^2 - n_2^2}$ $V = \frac{2\pi a}{\lambda} NA$ Single mode fiber: $V < 2.405$ Number of modes $M \approx \frac{V^2}{2}$ Photon energy $hf = E_c - E_v = E_g$ Plank's constant $h = 6.626 \times 10^{-34}$ Js $\lambda = \frac{c}{v} = \frac{hc}{E_g}$ Power absorbed $P(x) = P_0 (1-\exp[-\alpha_s(\lambda)x])$ where $\alpha_s(\lambda)$ is absorption coefficient Responsivity (PIN photodiode) $R = I_0/P_0$	For 2x2 coupler, with input power P_0 and output power P_2 & P_3: Coupling ratio $CR_{\%} = [P_2 / (P_2 + P_3)] \times 100$ Insertion loss $IL_{dB} = -10\log[P_2 / P_1]$ Excess loss $Pex_{dB} = -10\log[(P_2 + P_3)/P_1]$ Directivity $D_{dB} = -10\log[P_4 / P_1]$ Power, mW to dBm $P_{[dBm]} = 10 \log_{10} P_{[mW]}$ Gain (dB) $G_{[dB]} = P_{o[dBm]} - P_{i[dBm]}$