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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017

COURSENAME	:	OPTICAL COMMUNICATIONS
COURSE CODE	:	BEB 41603
PROGRAMME	:	BEJ
EXAMINATION DATE	:	JUNE 2017
DURATION	:	3 HOURS
INSTRUCTION	:	SECTION A: ANSWER **THREE (3)** QUESTIONS ONLY SECTION B: ANSWER THE **COMPULSORY** QUESTION

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THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

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SECTION A: ANSWER THREE(3) QUESTIONS ONLY

Q1 (a) Point out **FOUR(4)** applications of fiber optic and list **THREE(3)** main types of information that are usually carried by fiber optic cable.

(7 marks)

(b) Draw a basic fibre optic communication system and briefly explain its operation.

(6 marks)

(c) **THREE(3)** pieces of fibre optic cables, which the first cable has an attenuation of 0.5. The second and third cable have a similar attenuation of 0.65. All the cables are connected together each in series.

(i) Draw and label the block diagram.

(2 marks)

(ii) Find the total loss in dB.

(2 marks)

(iii) If a 17 mW signal is desired at the output cable, how much signal in dBm should be injected at the input?

(2 marks)

(d) The electric field of an electromagnetic wave is described by $E = 40\sin[(1.36 \times 10^{14})t - (9.66 \times 10^{6})z]$ volt/m.

(i) Write down and analyze the general expression of the electric field of an electromagnetic wave.

(2 marks)

(ii) Determine the frequency.

(2 marks)

(iii) Calculate the wavelength.

(2 marks)

Q2 (a) Attenuation coefficient can be expressed by the unit Neper/km or dB/km. Prove that 1 dB/km = 4.34 Neper/km.

(6 marks)

(b) Fibre dispersion can severely limit the useful bandwidth of the fibre. Several important dispersion parameters can cause the spreading of light pulse in time as it propagates down the fibre. With the aid of suitable diagrams, explain modal dispersion and show the related formula.

(7 marks)

(c) A silica fibre optical cable has a core with refractive index of 1.49 and a cladding with refractive index of 1.47. A light ray is injected into the core and its propagates along the cable. Determine :

(i) the critical angle at the core-cladding interface;

(2 marks)

(ii) the Numerical Aperture (NA) for the fibre; and

(2 marks)

(iii) the acceptance angle.

(2 marks)

(d) A beam of light is incident on a boundary between two dielectrics. The refractive indices are n_1 = 1.48 and n_2 = 1.46.If the light travel from n_1 to n_2 plot the transmitted angle as a function of the incident angle for incident angles from 0^0 to 90^0. Refer to the graph that you've plotted, give comment.

(6 marks)

Q3 (a) A continuous 10 km long fiber link has a loss of 12 dB.

(i) Calculate the minimum optimum power level that must be launched into the fiber to maintain an optical power level of 0.25 μW at the receiving end.

(2 marks)

(ii) Refer to **Q3(a)(i)**, find output power P_{OUT} in dBm if only 60 % of the source power enter the fibre optic cable.

(3 marks)

(iii) Refer to **Q3(a)(i)**, determine the required input power if the fiber has an attenuation coefficient of 2.0 dB/km.

(2 marks)

(b) Describe with the aid of diagram the two processes that are inherent to laser operation listed below:

(i) stimulated emission; and

(3 marks)

(ii) population inversion.

(3 marks)

(c) A Fabry Perot laser active region has a reflective index of 3.66 and a cavity length of 1.55 mm. If the laser has a dominant mode output of 7mW and a secondary mode output of 1mW, determine:

(i) mode separation ; and

(3 marks)

(ii) mode suppression ratio.

(3 marks)

(d) Light Emitting Diode (LED) guiding region emits 9 mW and has a refractive index of 3.61 at the operating wavelength. For a diode current of 20 mA, determine:

(i) the external quantum efficiency;

(2 marks)

(ii) the power leaving the LED surface; and

(2 marks)

(iii) the responsivity.

(2 marks)

Q4 (a) Give the **THREE (3)** advantages and disadvantages of laser diode (LD) compare to light emitting diode (LED).

(6 marks)

(b) A silicon photodetector has the following specifications: responsivity is 0.5 A/W and the 3 dB bandwidth is 500 MHz. Determine:

(i) the current which will be produced when the photodetector is incident by a ray of -45 dBm; and

(3 marks)

(ii) the rise time of the photodetector.

(4 marks)

(c) Photons of 3×10^{11} each with a wavelength of 0.85 μm are incident on a photodiode resulting an average of 1.2×10^{11} electrons are being collected at the terminals of the device. Determine :

(i) the quantum efficiency; and

(3 marks)

(ii) the responsivity of the photodiode.

(3 marks)

(d) A 2x2 four-port biconical tapered coupler has an input power of 20 mW and output powers of 8 mW and 9 mW at Port 3 and Port 4 respectively. If the power at port 2 is 2 mW, determine:

(i) the insertion loss at Port 4;

(2 marks)

(ii) the coupling ratio; and

(2 marks)

(iii) the excess loss.

(2 marks)

SECTION B: ANSWER THE COMPULSORY QUESTION

Q5 (a) MBO company will construct a telecommunication infrastructure of 10 Gbps using 40 km optical fiber link. As an engineer in this company, you are assigned to design the link based on the available components as shown in **Table Q5**. Fiber splice will be used to join the optical fiber. The splice loss is 0.2 dB/splice. Connectors are required at transmitter and receiver. Suggest your setup based on the provided components by considering power and rise time budget if non return zero (NRZ) modulation is used. The power margin of 6 dB should be added in your estimation.

(20 marks)

(b) Advance modulation technique is a potential candidate for upgrading the capacity of data transportation per channel wavelength in optical communication system. Give your opinion to support this statement.

(5 marks)

- END OF QUESTIONS -

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Table Q5: Parameters

Transmitter 1	Direct modulated DFB laser λ=1570 nm output power = 1 mW rise time = 20 ps spectral width = 0.1 nm
Transmitter 2	Continuous wave DFB laser λ=1570 nm output power = 1 mW rise time = 20 ps spectral width = 0.01 nm
Receiver 1	InGaAs p-i-n rise time = 20 ps, receiver sensitivity = -17 dBm at BER of 10^{-9}
Receiver 2	InGaAsAPD rise time = 25 ps, receiver sensitivity = -24 dBm at BER of 10^{-9}
Optical Modulator	Insertion loss = 6 dB
Fiber	Single mode fiber available lengths = 5 km / drum attenuation = 0.2 dB/km at 1570 nm dispersion = 17ps/(km.nm) at 1570 nm
Connector	Loss = 1 dB/connector

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Constants

Planck's constant, h = 6.626 x 10^{-34} J.s

Boltzmann's constant, K=1.381 x 10^{-23} $J.K^{-1}$

Electron charge, e =1.602 x 10^{-19} Coulomb

Velocity of light in vacuum, c = 2.998 x 10^8 m/s

Formula

$V = \frac{2\pi}{\lambda} a n_1 (2\Delta)^{\frac{1}{2}}$	$\tau_g = \frac{1}{c}\left(n_1 - \frac{\lambda d n_1}{d\lambda}\right)$	$\tau_m = \frac{L}{c}\left(n_1 - \frac{\lambda d n_1}{d\lambda}\right)$	$\sigma_m = \frac{\sigma_\lambda L}{c}\left(\lambda \frac{d^2 n_1}{d\lambda^2}\right)$
$\tau_s = \frac{(NA)^2}{2cn_1}$	$\tau_g = \frac{n_1 \Delta^2}{8c}$	$\sigma_s = \frac{L n_1 \Delta}{2\sqrt{3}c}$	$\sigma_s = \frac{L(NA)^2}{4\sqrt{3}n_1 c}$
$\sigma_T = (\sigma_m^2 + \sigma_s^2)^{\frac{1}{2}}$	$B_T = \frac{0.2}{\sigma} bits/\sec$	$B_T = \frac{1}{2\tau} bits/\sec$	$BW = B_T(RZ)$
$BW = \frac{1}{2} B_T(NRZ)$	$\eta_{int} = \frac{1}{1 + \tau_r/\tau_{nr}} = \frac{\tau}{\tau_r}$	$P_{int} = \eta_{int}\frac{I_p}{e} h\upsilon = \eta_{int}\frac{hcI_p}{e\lambda}$	$\eta_{ep} = \frac{P_e}{P}, where\, P = IV$
$\eta_{ext} = \eta_{int} F t T$	$F = \frac{n_a^2}{2n_S^2}$	$t = \frac{4n_S n_a}{(n_S + n_a)^2}$	$T = 1 - a_S$
$P_e = \frac{P_{int} F n^2}{4n_x^2}$	$r_e = \frac{I_p}{e}$	$r_p = \frac{P_o}{hf}$	$L = \frac{\lambda}{2n} q$
$\Delta\lambda = \frac{\lambda^2}{2nL}$	$\Delta f = \frac{c}{2nL}$	$R = \frac{\eta e \lambda}{hc} = \frac{I_p}{P_0}$	$\bar{i^2_{shot}} = 2eB(I_p + I_d)(A^2)$
$\bar{i^2_{th}} = \frac{4KTB}{R}(A^2)$	$SNR = \frac{S}{N} = \frac{I_p^2}{\bar{i^2_{shot}} + \bar{i^2_{th}} + \bar{i^2_{amp}}}$		$SNR = \frac{S}{N} = \frac{M^2 I_p^2}{\bar{i^2_{shot}} M^{2+x} + \bar{i^2_{th}} + \bar{i^2_{amp}}}$
$f_{3dB} = (2\pi R_L C_d)^{-1}$	$\tau = \frac{0.7}{B_{NRZ}}$	$\tau_{chrom} = \lvert D \rvert \times L \times \Delta\lambda$	$t_{PD} = 2.19 R_L C_D$
$IL = 10\, log\left(\frac{P_1}{P_4}\right)$	$CR = \left(\frac{P_3}{P_3 + P_4}\right) x\, 100\%$	$CTalk = 10\, log\left(\frac{P_2}{P_1}\right)$	$EL = 10\, log\left(\frac{P_1}{P_3 + P_4}\right)$
$\tau_s = \sqrt{\tau_f^2 + \tau_{TX}^2 + \tau_{RX}^2}$	$\Lambda = \frac{\lambda_B}{2_n}$	$V = \frac{2\pi\, a}{\lambda}\sqrt{n_1^2 - n_2^2}$	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$D(\lambda) = \frac{S_0}{4}\left(\lambda - \frac{\lambda_{ZD}^4}{\lambda^3}\right) ps/nm.km$	$\Delta\lambda = \frac{\lambda^2}{c}\Delta f$	$OSNR = P_{in} + 58 - L_S - NF - 10\log(N_A)$	