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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2015/2016

COURSE NAME	:	OPTICAL COMMUNICATIONS
COURSE CODE	:	BEB 41603
PROGRAMME	:	BACHELOR OF ELECTRONIC ENGINEERING WITH HONORS
EXAMINATION DATE	:	DECEMBER 2015/ JANUARY 2016
DURATION	:	3 HOURS
INSTRUCTION	:	SECTION A: ANSWER **ALL** QUESTIONS SECTION B: ANSWER **TWO (2)** QUESTIONS ONLY SECTION C: ANSWER **ONE (1)** QUESTION ONLY

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

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SECTION A: ANSWER ALL QUESTIONS

Q1 (a) Describe the mechanism of a light travelling in an optical fiber using simple ray theory with the aid of relevant diagram.

(5 marks)

(b) A single mode fiber which has a core diameter of 9 µm and core index of 1.588 is propagating a light at wavelength of 1550 nm.

(i) Identify the normalized cut- off frequency *V*, for your calculation.

(1 mark)

(ii) Calculate the minimum cladding index.

(2 marks)

(iii) Calculate the critical propagation angle.

(2 marks)

Q2 (a) List two types of optical coupler that are available in the market.

(2 marks)

(b) You are required to characterize a biconical-tapered coupler of unknown specification as shown in Figure **Q2(b)**. The power injected from the laser source into the coupler is 5 mW. The measured output power shows a reading of 0.7 mW, 2.8mW and 1.5 µW for P_2, P_3 and P_4, respectively. Determine the:

(i) coupling ratio;

(2 marks)

(ii) insertion loss;

(2 marks)

(iii) excess loss; and

(2 marks)

(iv) directivity.

(2 marks)

Q3 (a) Imagine you are attending an interview for the post of communication engineer in one of the famous communication provider company in Malaysia. The interviewers were interested to know about transmission source for long haul transmission network. Suggest a suitable transmission source and convince the interviewers of your choice.

(5 marks)

(b) Comment on the suitability of PIN photodiode as light detector in optical communication systems.

(5 marks)

Q4 (a) Signal power attenuation can be compensated using an optical amplifier. However, the signal recovering process in the optical amplifier results in the addition of amplified spontaneous emission (ASE) to the signal. From the statement given, point out at least two opinions to support this argument.

(5 marks)

(b) The deployment of 7,800 km Asia optical fiber based link submarine cable express that connects Japan, Philippines, Singapore and Malaysia, shows the Malaysian government initiative in realizing high speed broadband throughout the region. In your opinion, explain the impact of high speed internet access in societal and global context.

(5 marks)

SECTION B: ANSWER TWO (2) QUESTIONS ONLY

Q5 (a) Explain briefly the operation of Fiber Bragg grating (FBG) with the help of a diagram.

(5 marks)

(b) FBG is developed within a fiber core which has a refractive index of 1.46. Determine the grating period of the FBG to reflect an optical signal with a wavelength of 1.55 μm.

(2 marks)

(c) List three (3) applications of FBG in optical communication systems.

(3 marks)

(d) A laser diode with an input power of 0.5 mW is launched into a fiber with a launch amplifier which has a gain of 25 dB. The length of the fiber is 100 km and has attenuation rating of 0.25 dB/km. The output is fed into an inline amplifier having sufficient gain to bring the power level back to the same level as the output power of the launching amplifier. The output is then fed into another fiber which has the same attenuation but has length of 150 km. A preamplifier at the receiver boosts the output power level to 0.5 mW.

(i) Compute the gain of the preamplifier.

(8 marks)

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

(2 marks)

Q6 (a) UniFi is a broadband service by Telekom Malaysia (TM) that uses optical fiber to deliver high speed internet, phone and internet protocol TV (IPTV) services to customers' home. 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 is suitable to describe the UniFi systems.

(10 marks)

(b) In telecommunications and computer networks, multiplexing (sometimes contracted to muxing) is a method where multiple analog message signals or digital data streams are combined into one signal over a shared medium. Discuss the importance of multiplexing in today's communication technology.

(3 marks)

(c) Consider the current-to-voltage converter in the Figure **Q6(c)**. The PIN detector has a responsivity of 0.5 μA/μW and the incident optical power is -34 dBm. The feedback resistance is 10kΩ and the shunt capacitance of the feedback network is 0.2 pF. Compute

(i) the output voltage; and

(5 marks)

(ii) the 3-dB bandwidth

(2 marks)

Q7 (a) An optical communication link is designed to transmit data over a single mode optical fiber of 100 km, with fiber loss of 0.2 dB/km, six splices with 0.05 dB per splice loss, and two connectors with 0.2 dB per connector. The receiver sensitivity is 20 μW. Identify the minimum transmitter power (express in both mW and dBm).

(10 marks)

(b) By referring to **Q7(a)**, the transmitter operates at 2.5 Gbps at a central wavelength of 1550 nm, with a spectral linewidth 0.5 nm. If the fiber has a dispersion parameter of −20 ps/nm·km, then will the system work? Show the calculation to support your answer.

(6 marks)

(c) Identify the minimum length required for a dispersion compensating fiber with a dispersion parameter of 100 ps/nm·km placed at the end of the link to achieve the intended bit rate.

(4 marks)

SECTION C: ANSWER ONE (1) QUESTION ONLY

Q8 As a fresh engineer in MBO Company, you are required to design a fiber optic system link operating at 10 Gbps. The minimum optical transmitter launch power is –7.5 dBm, and the maximum optical transmitter launch power is 0 dBm at 1550 nm. The minimum receiver sensitivity is –30 dBm, and the maximum receiver sensitivity is –3 dBm at 1550 nm. Assume an inclusion of two patch panels in the path, eight fusion splices, with the system operating over 50 km of step index 8.1/125-m single mode fiber (SMF) cable. The full specification of the fiber characteristics, component loss and reference margin values can be found in Table **Q8(a), Q8(b)** and **Q8(c)**.

Self phase modulation (SPM), polarization mode dispersion PMD, and stimulated Raman scattering/stimulated Brillouin scattering (SRS/SBS) margin requirements must be considered in the system if needed.

(a) Give a strong justification why you include or do not include those parameters such as fiber characteristics, component loss and reference margin values in your design.

(16 marks)

(b) Determine whether the system comply with the power margin and the receiver sensitivity design equation.

(4 marks)

Q9 An optical fiber communication link (point-to-point) need to be laid for new telecommunication company. The transmission distance is 50 km with 10 Gbps non return zero (NRZ) optical signal. The bit error rate (BER) is 10^{-9} and the minimum system margin is 5dB. Table **Q9** shows the characteristics of the optical network.

As an engineer you are required to:

(a) Illustrate the network using suitable block diagram.

(2 marks)

(b) Determine the power as well as the bandwidth budget.

(15 marks)

(c) Comment on the outcome of the design.

(3 marks)

- END OF QUESTIONS -

FINAL EXAMINATION

SEMESTER/SESSION: SEMESTER I/2015/2016
COURSE NAME: OPTICAL COMMUNICATIONS

PROGRAMME: BEJ
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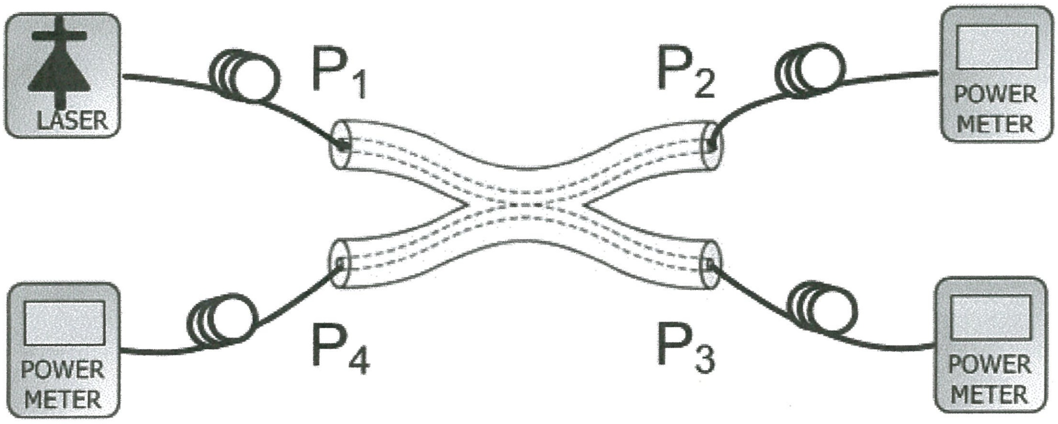

FIGURE Q2(b):Biconical-tapered coupler

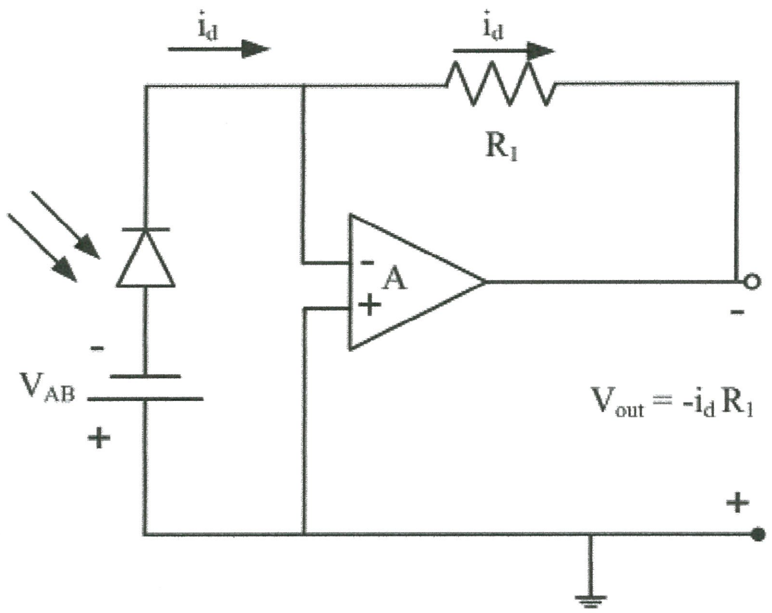

FIGURE Q6(c):Current to voltage converter

FINAL EXAMINATION

SEMESTER/SESSION: SEMESTER I/2015/2016
COURSE NAME: OPTICAL COMMUNICATIONS

PROGRAMME: BEJ
COURSE CODE: BEB 41603

Table Q8(a): Typical Fiber-Attenuation Characteristics

Mode	Material	Refractive Index Profile	λ (nm)	Diameter (μm)	Attenuation (dB/km)
Multimode	Glass	Step	800	62.5/125	5.0
Multimode	Glass	Step	850	62.5/125	4.0
Multimode	Glass	Graded	850	62.5/125	3.3
Multimode	Glass	Graded	850	50/125	2.7
Mode	**Material**	**Refractive Index Profile**	**λ (nm)**	**Diameter (μm)**	**Attenuation (dB/km)**
Multimode	Glass	Graded	1310	62.5/125	0.9
Multimode	Glass	Graded	1310	50/125	0.7
Multimode	Glass	Graded	850	85/125	2.8
Multimode	Glass	Graded	1310	85/125	0.7
Multimode	Glass	Graded	1550	85/125	0.4
Multimode	Glass	Graded	850	100/140	3.5
Multimode	Glass	Graded	1310	100/140	1.5
Multimode	Glass	Graded	1550	100/140	0.9
Multimode	Plastic	Step	650	485/500	240
Multimode	Plastic	Step	650	735/750	230
Multimode	Plastic	Step	650	980/1000	220
Multimode	PCS	Step	790	200/350	10
Single-mode	Glass	Step	650	3.7/80 or 125	10
Single-mode	Glass	Step	850	5/80 or 125	2.3
Single-mode	Glass	Step	1310	9.3/125	0.5
Single-mode	Glass	Step	1550	8.1/125	0.2
Single-mode	Glass	Dual Step	1550	8.1/125	0.2

FINAL EXAMINATION

SEMESTER/SESSION: SEMESTER I/2015/2016
COURSE NAME: OPTICAL COMMUNICATIONS

PROGRAMME: BEJ
COURSE CODE: BEB 41603

Table Q8(b): Component Loss Values

Component	Insertion Loss
Connector Type	
SC	0.5 dB
ST	0.5 dB
FC	0.5 dB
LC	0.5 dB
MT-RJ	0.5 dB
MTP/MPO	0.5 dB
Splice	
Mechanical	0.5 dB
Fusion	0.02 dB
Fiber patch panel	2.0 dB

Table Q8(c): Reference Margin Values

Characteristic	Loss Margin	Bit Rate	Signal Power
Dispersion margin	1 dB	Both	Both
SPM margin	0.5 dB	High	High
XPM margin (WDM)	0.5 dB	High	High
FWM margin (WDM)	0.5 dB	Both	High
SRS/SBS margin	0.5 dB	High	High
PMD margin	0.5 dB	High	Both

FINAL EXAMINATION

SEMESTER/SESSION: SEMESTER I/2015/2016 PROGRAMME: BEJ
COURSE NAME: OPTICAL COMMUNICATIONS COURSE CODE: BEB 41603

Table Q9: Characteristic properties of the devices

Transmitter:	DFB laser λ=1580 nm, output power = 10 mW, rise time = 76 ps, spectral width = 0.7 pm, coupling loss to fiber = 7 dB.
Fiber:	Single mode fiber available lengths = 7 km, attenuation = 0.2 dB/km, dispersion = 20 ps/(km.nm)
Connectors:	Loss = 1 dB/connector (one at the transmitter and one at the receiver)
Splices:	Loss = 0.2 dB/splice
Detector:	InGaAs p-i-n RC- limited bandwidth = 4 GHz, coupling loss from the fiber = 1dB, receiver sensitivity = -25 dBm for BER= 10^{-9}

FINAL EXAMINATION

SEMESTER/SESSION: SEMESTER I/2015/2016
COURSE NAME: OPTICAL COMMUNICATIONS

PROGRAMME: BEJ
COURSE CODE: BEB 41603

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

$V=\frac{2\pi}{\lambda}an_1(2\Delta)^{\frac{1}{2}}$	$\tau_g=\frac{1}{c}\left(n_1-\frac{\lambda dn_1}{d\lambda}\right)$	$\tau_m=\frac{L}{c}\left(n_1-\frac{\lambda dn_1}{d\lambda}\right)$	$\sigma_m=\frac{\sigma_\lambda L}{c}\left(\lambda\frac{d^2n_1}{d\lambda^2}\right)$
$\tau_s=\frac{(NA)^2}{2cn_1}$	$\tau_g=\frac{n_1\Delta^2}{8c}$	$\sigma_s=\frac{Ln_1\Delta}{2\sqrt{3}c}$	$\sigma_s=\frac{L(NA)^2}{4\sqrt{3}n_1c}$
$\sigma_T=(\sigma_m^2+\sigma_s^2)^{\frac{1}{2}}$	$B_T=\frac{0.2}{\sigma}bits/\sec$	$B_T=\frac{1}{2\tau}bits/\sec$	$BW=B_T(RZ)$
$BW=\frac{1}{2}B_T(NRZ)$	$\eta_{int}=\frac{1}{1+\tau_r/\tau_{nr}}=\frac{\tau}{\tau_r}$	$P_{int}=\eta_{int}\frac{I_P}{e}h\upsilon=\eta_{int}\frac{hcI_P}{e\lambda}$	$\eta_{ep}=\frac{P_e}{P}, where\ P=IV$
$P_e=\frac{P_{int}Fn^2}{4n_x^2}$	$r_e=\frac{I_P}{e}$	$r_p=\frac{P_o}{hf}$	$L=\frac{\lambda}{2n}q$
$\Delta\lambda=\frac{\lambda^2}{2nL}$	$\Delta f=\frac{c}{2nL}$	$R=\frac{\eta e\lambda}{hc}=\frac{I_P}{P_0}$	$\bar{i}_{shot}^2=2eB(I_p+I_d)(A^2)$
$\bar{i}_{th}^2=\frac{4KTB}{R}(A^2)$	$SNR=\frac{S}{N}=\frac{I_P^2}{\bar{i}_{shot}^2+\bar{i}_{th}^2+\bar{i}_{amp}^2}$		$SNR=\frac{S}{N}=\frac{M^2I_P^2}{\bar{i}_{shot}^2M^{2+x}+\bar{i}_{th}^2+\bar{i}_{amp}^2}$
$f_{3dB}=(2\pi R_LC_d)^{-1}$	$\Delta\tau=\frac{0.7}{B_{NRZ}}$	$\Delta\tau_{chrom}=-M\times L\times\Delta\lambda$	$t_{PD}=2.19R_LC_D$
$t_s=\sqrt{t_f^2+t_r^2+t_{PD}^2}$	$\Lambda=\frac{\lambda_B}{2_n}$	$V=\frac{2\pi a}{\lambda}\sqrt{n_1^2-n_2^2}$	$n_1\sin\theta_1=n_2\sin\theta_2$