



UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: March 2022

Module Number: EE7211

Module Name: Optical Fiber Communication

[Three Hours]

[Answer all questions, each question carries 10 marks]

- All the notations have their usual meaning.
- Use the following parameters, if required.

Planck's Constant = 6.626×10^{-34} J. s Charge of an Electron = 1.602×10^{-19} C

Boltzmann Constant = 1.38×10^{-23} m². kg. s⁻². K⁻¹

Q1 a) Distinguish between meridional rays and skew rays used in optical wave propagation.

[2.0 Marks]

b) The refractive index profile of the graded index fiber is given by

$$n(r) = \begin{cases} n_1 [1 - 2\Delta]^{1/2} = n_1 (1 - \Delta) = n_2 & \text{for } r \geq a \\ n_1 \left[1 - 2\Delta \left(\frac{r}{a} \right)^\alpha \right]^{1/2} & \text{for } 0 \leq r \leq a \end{cases}$$

where r is the radial distance from the fiber axis, a is the core radius, n_1 is the refractive index at the core axis, n_2 is the refractive index of the cladding and the dimensionless parameter α defines the shape of the index profile. Moreover, the relative refractive index difference Δ for the graded index fiber is

$$\Delta = \frac{n_1 - n_2}{n_1}$$

- Draw the refractive profile for graded index fiber.
- Obtain an expression for numerical aperture of the step index fiber by approximating the expressions stated above.

[3.0 Marks]

c) i) Calculate the number of modes at 820 nm and 1.3 μ m in a graded index fiber having a parabolic index profile ($\alpha = 2$), a 25 μ m core radius, $n_1 = 1.48$ and $n_2 = 1.46$.

ii) How do you compare the value obtained in part i) to a step index fiber?

[5.0 Marks]

- Q2 a) Briefly explain the following.
- i) Dispersion and pulse broadening
 - ii) Intramodal dispersion and Intermodal dispersion
 - iii) Rayleigh scattering and Mie scattering
- [4.5 Marks]
- b) Consider a standard non-dispersion shifted single mode optical fiber that has a zero-dispersion wavelength at 1310 nm with a dispersion slope of $S_0 = 0.090$ ps/(nm². km). Plot the dispersion in the wavelength range ($1270 \leq \lambda \leq 1340$) nm.
- [1.5 Marks]
- c) A typical dispersion shifted single mode optical fiber has a zero-dispersion wavelength at 1550 nm with a dispersion slope $S_0 = 0.070$ ps/(nm². km).
- i) Plot the dispersion in the wavelength range ($1500 \leq \lambda \leq 1600$) nm.
 - ii) Compare the dispersion at 1500 nm with the dispersion value for the non-dispersion shifted fiber described in part b).
 - iii) Sketch the refractive index profiles of the dispersion shifted single mode optical fiber and the non-dispersion shifted fiber.
 - iv) Explain how it is possible to shift the zero-dispersion wavelength of dispersion shifted fiber to a higher wavelength.
- [4.0 Marks]
- Q3 a) With the help of illustrations, explain the difference of construction and working principles of surface emitting and edge emitting LEDs.
- [2.0 Marks]
- b) The radiative and non-radiative recombination lifetimes of the minority carriers in the active region of a double-heterojunction LED are 60 ns and 100 ns respectively.
- i) Determine the total carrier recombination lifetime.
 - ii) What is the power generated within the device when the peak emission wavelength is 0.87 μ m at a drive current of 40 mA?
- [5.0 Marks]
- c) i) What are the main responsibilities of a transmitter in an optical fiber communication system?
- ii) Briefly explain two source-to-fiber coupling mechanisms used in optical transmitters?
- [3.0 Marks]
- Q4 a) What is meant by detector response time? Explain the factors that affect to the response time of a detector.
- [2.0 Marks]
- b) Briefly explain the optical detection principle of a *p-i-n* photodiode.
- [3.0 Marks]

- c) A silicon avalanche photodiode has a quantum efficiency of 65% at a wavelength of 900 nm.
- Determine the responsivity of the photodiode.
 - Assuming $0.5 \mu\text{W}$ of optical power to the photodiode produces a multiplied photocurrent of $10 \mu\text{A}$, find the multiplication factor of the photodiode.

[5.0 Marks]

- Q5 a) A schematic diagram of a typical receiver is shown in Figure Q5. Identify the basic stages of the receiver and briefly explain the functions of each stage.

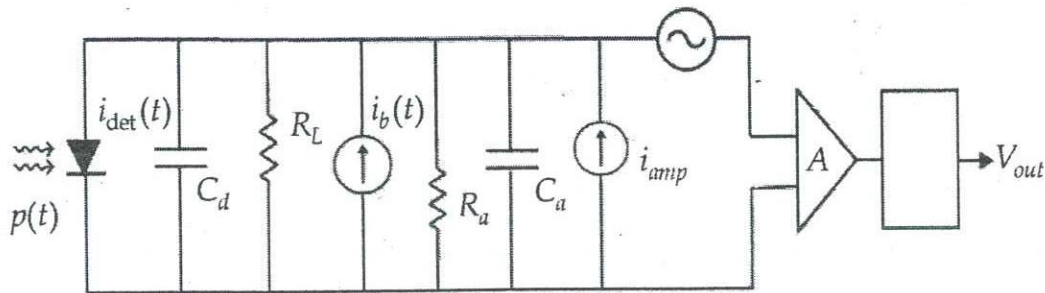


Figure Q5

Note:

You should redraw the diagram on the answer script and show the stages clearly.

[3.0 Marks]

- b) A silicon *p-i-n* photodiode integrated into an optical receiver has a quantum efficiency of 60% when operating at a wavelength of 900 nm. The dark current in the device at this operating point is 3 nA and the total capacitance is 4 kΩ. The incident optical power to the photodiode is 200 nW and the post detection bandwidth of the receiver is 5 MHz at a temperature of 20°C. Determine the
- total shot noise
 - thermal noise and
 - SNR at the output of the receiver assuming the receiver has a noise figure of 3 dB.

Hint:

$$\frac{S}{N} = \frac{I_p^2}{2eB(I_p + I_d) + \frac{4KTB F_n}{R_L}}$$

[7.0 Marks]