KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN COMPUTER ENGINEERING

SCE 525: OPTICAL COMMUNICATIONS

DATE: Tuesday 10th April, 2012 **TIME:** 11.00 a.m. – 1.00 p.m.

INSTRUCTIONS

Attempt Questions ONE and any other TWO questions.

QUESTION ONE

a) (i) Sketch a well labelled block schematic of a typical digital optical fiber and briefly describe its operation. (7 Marks)

(ii) The optical carrier can be modulated in two ways: Digital and analogue. Differentiate between the two and give one advantage of each (4 Marks)

b) Give and explain **five** advantages and **four** limitations of optical fiber communications. (9 Marks)

c) By use of a well labelled diagram, describe the operation of a laser system. (6 Marks)

d) One important feature of lasers is the spectral width. Give and explain **four** points to show its significance. (4 Marks)

QUESTION TWO

a) Estimate the irradiance of a 1 mW laser beam with diameter of 1mm. (2 Marks)

b) Give two conditions necessary for total internal reflection to occur. (2 Marks)

c) Compute the velocity and wavelength of light of frequency $f = 0.5 \times 10^{15}$ Hz when travelling through a glass having a refractive index of $n = 1.5$. (2 Marks)

d) What is the difference between step-index and graded-index multimode fibers? Draw their respective cross-sections. (6 Marks)

e) Sketch and explain the operation of a **four-level** atomic system. Using its rate equations, show that there is almost no threshold for the pumping rate to generate population inversion. (8 Marks)

QUESTION THREE

a) A graded index fiber has a core with a parabolic refractive index profile which has a diameter of 50 μm. The fiber has numerical aperture of 0.2. Estimate the total number of guided modes propagating in the fiber when it is operating at a wavelength of 1μm. (4 Marks)

b) Give and explain four characteristics of lasers. (4 Marks)

c) GEOBEL Technologies, a new entrant in the communication industry, is considering the installation of fiber optic cables between two sites that are 1370 miles apart. GEOBEL is considering two types of fibers: **f1** and **f2**. Both types have a bandwidth of 2.007 GHz, with a signal-to-noise ratio (SNR) of 10,000 (i.e., 40 dB) at the originating source. However, as the signal is transmitted over the fiber optic cable, its SNR degrades (drops). For **f1**, the degradation rate is 0.1 dB per mile, while that for **f2** is 0.125 dB per mile. When the SNR degrades to a certain threshold, a 2.007 GHz repeater can be used to recreate the signal so that the SNR becomes 10,000 again.

(i) If GEOBEL wants to achieve a data rate of 20 Gbps, what repeater spacing should they use for **f1**? What repeater spacing should they use for **f2**? (4 Marks)

(ii) Based on your calculations in part (i), determine how many repeaters would be needed in each case. (4 Marks)

(iii) The current market prices of the installed fiber optic cables are \$25/mile for **f1** and \$20/mile for **f2**. Determine the price of a 2.007 GHz repeater if GEOBEL is indifferent between the two media choices. (4 Marks)

QUESTION FOUR

a) A 0.85 μm optical communication system transmits data over a 10 km single mode fiber. The dispersion parameter of the fiber is D = 20 ps/(km-nm). The LED has a spectral width $\Delta\lambda$ of 10 nm. Determine the maximum bit rate possible. (5 Marks)

b) A 1km fiber has a core and cladding indices of $n_1 = 1.48$ and $n_2 = 1.46$. The core diameter is $50\ \mu$m. Find

(i) The minimum angle that supports total internal reflection (2 Marks)

(ii) The time delay of an off-axis ray compared to a ray that propagates directly down the fiber and (5 Marks)

(iii) An estimate of the modal-dispersion-limited bandwidth (2 Marks)

c) Give the three main functions of the cladding material in fiber optic cables. (3 Marks)

d) What do you understand by the following terms?

(i) Absorption

(ii) Stimulated emission

(iii) Population inversion (3 Marks)

QUESTION FIVE

a) Silica has an estimate fictive temperature of 1400 K with an isothermal compressibility of $7\times10^{-10}\ \mathrm{m^2N^{-1}}$. The refractive index and the photo-elastic coefficient for silica are 1.46 and 0.286 respectively. Determine the theoretical attenuation in decibels per kilometre due to the fundamental Rayleigh scattering in silica at optical wavelengths of 0.63, 1.00 and 1.30 μm. Boltzmann's constant is $1.381\times10^{-23}\ \mathrm{JK^{-1}}$. (10 Marks)

b) Calculate the wavelength of emission when an atom de-excites from an energy state at 12.09 eV to one at 10.2 eV above the ground state. Planck's constant $h = 6.626\times10^{-34}$ Js and the electron charge $q = 1.6\times10^{-19}$ C. (4 Marks)

c) Explain the difference between chromatic dispersion and multimode dispersion in optical fibers. (2 Marks)

d) A multiple graded index fiber exhibits total pulse broadening of $0.1\,\mu s$ over a distance of $15\,km$. Estimate

(i) the maximum possible bandwidth on the link assuming no inter-symbol interference (2 Marks)

(ii) the pulse dispersion per unit length (1 Mark)

(iii) the bandwidth-length product for the fiber (1 Mark)