OLLSCOIL NA hÉIREANN, CORCAIGH
THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

AUTUMN EXAMINATIONS, 2003

B.E. DEGREE (ELECTRICAL)
HIGHER DIPLOMA IN PHYSICS

OPTICAL ELECTRONICS
EE4007

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Professor R. Yacamini
Dr. S.L. Prunty
Dr. A.P. Morrison

Time Allowed: *3 hours*

FIVE QUESTIONS TO BE ANSWERED, AT LEAST TWO FROM EACH SECTION.
USE SEPARATE ANSWER BOOKS FOR EACH SECTION

The use of a Casio fx570w or fx570ms calculator is permitted.

Physical Constants:

Free electron mass, m_0 = 9×10^{-31} kg
Planck's constant, h = 6.626×10^{-34} J s
Electronic charge, q = 1.602×10^{-19} C
Boltzmann's constant, k_B = 1.38×10^{-23} J K^{-1}
Room temperature = 300 K
Speed of light in free space, c = 3×10^{8} m s^{-1}

SECTION A

1. (a) Sean’s question one

2. (a) Sean’s question two

3. (a) Sean’s question three

4. (a) Sean’s question four

SECTION B

5. (a) Draw and label a block-diagram representation of a broadcast optical communication system. [*4 marks*]

   (b) Explain the following terms:

   i. Modal distortion
   ii. Polarisation mode dispersion
   iii. Bit-error rate
   iv. Fibre attenuation
   v. Link margin

   [*5 marks*]

   (c) A point-to-point optical fibre link is to be designed between Cork and Dublin (distance 260 km). The desired link margin is +15 dB. The laser chosen has an average output power of 8mW at a wavelength of 1.55 μm. The sensitivity of the chosen receiver is -32 dBm (this includes all collection losses). Modulation loss and fibre coupling loss may be taken as a total of 5.8 dB. The single mode fibre used for the link has an attenuation of 0.28 dB km^{-1} at 1.55 μm. Erbium doped fibre amplifiers are to be used to boost the optical signal. These amplifiers come in 5 m lengths and will provide 5 dB gain. How many of these EDFAs will be required to ensure the desired link margin? Where would they be placed? You may assume that fibre dispersion and non-linearity are insignificant, also assume fibre splice loss to be 0.15 dB. All fibre ends are properly terminated with low reflection loads. [*11 marks*]

6. (a) Calculate the reflectance at normal incidence for a ray of light striking a plane glass surface. (refractive index for air = 1, glass = 1.5). What is the value of the reflection coefficient? [*4 marks*]

   (b) What is meant by s-polarisation and p-polarisation? [*4 marks*]

   (c) What is the Brewster angle? What value is the Brewster angle for the air/glass interface? [*4 marks*]

   (d) If air/glass/air were used to form a symmetric slab waveguide, what thickness should the glass be to guarantee single mode operation at a wavelength of 650 nm? [*4 marks*]

   (e) What is the critical angle for the waveguide described in part (d)? [*4 marks*]

7. (a) Draw the simplified band diagram for Silicon and GaAs. Label the Γ, X and L valleys, the heavy-hole band, the light-hole band and the split-off band. [*4 marks*]

   (b) Outline three advantages of III-V semiconductors over silicon in the design and fabrication of light emitting diodes. [*6 marks*]

   (c) A single quantum well double heterostructure laser diode is to operate at λ = 855 nm. The quantum well is infinitely deep and the well material has a bandgap energy of 1.2 eV. If the electron effective mass and the heavy-hole effective mass were both one tenth of the free electron mass, what width should the quantum well be to provide the required emission wavelength? [*10 marks*]

8. (a) Calculate the responsivity of a silicon photodiode at 100 nm intervals from 400 nm to 900 nm. Plot the responsivity versus wavelength graph. You may assume the quantum efficiency of the detector is 100% at all wavelengths. [*5 marks*]

(b) Describe the role of impact ionisation in the operation of avalanche photodiodes. [*5 marks*]

(c) A photodiode having a circular active area of 1 cm radius has a responsivity of 0.55 A/W to light at 633 nm. The noise equivalent power for the photodiode is 2.5×10^{-12} W $\text{Hz}^{-1/2}$. This photodiode is to be used in a LIDAR (Light detection and ranging) system in conjunction with a He-Ne laser having a non-divergent beam with 5 mW average output power. Assume no attenuation of the laser light, a bandwidth of 1 Hz and assume the target is a perfect diffuse reflector (i.e. reflected light is scattered uniformly in all directions) - what is the maximum target distance that can be measured in this system? What is the photocurrent produced? [*10 marks*]