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

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

AUTUMN EXAMINATIONS, 2007

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

OPTICAL ELECTRONICS
EE4007

Prof. Dr. U. Schwalke
Professor P.J. Murphy
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.
The use of Log Tables and Graph paper are 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. Sean Question 1

2. Sean Question 2

3. Sean Question 3
4. Sean Question 4

SECTION B

5. A point-to-point optical fibre link uses an LED light source producing pulses of 10 ns duration and a 30% duty cycle. The LED is operating at 1.55 μm and has a spectral linewidth of $\Delta\lambda$=20 nm. The fibre used is multi-mode and has an attenuation of 0.2 db/km. The average power launched into the fibre is 3 mW and the measured average output power is 0.1 mW. (Assume the coupling and isolator losses are negligible.)

   (a) For the conditions described, what is the length of the link? [*5 marks*]

   (b) If the fibre has a material dispersion of 110 ps/nm.km at 1.3 μm and 40 ps/nm.km at 1.7 μm, what is the total pulse spread for this link? (Assume material dispersion varies linearly with wavelength). [*5 marks*]

   (c) What type of fibre could be used to make the dispersion close to zero for this system? What would its refractive index profile look like? Why could the dispersion never be zero? [*5 marks*]

   (d) What is the photon arrival rate? [*5 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) List five differences between Light-emitting diodes (LEDs) and Laser diodes.

[*4 marks*]

(b) What peak emission wavelength is to be expected from an LED having an active region with a band-gap of 2.4 eV? Draw the spectral output if $\Delta\lambda$ = 20 nm.

[*4 marks*]

(c) Describe how an indirect band-gap material, such as GaP, can be used to make a light-emitting diode.

[*3 marks*]

(d) A GaAs/AlGaAs LED has an activation barrier of energy E_d = 0.82 eV to long-term degradation. If the prefactor in the Arrhenius equation describing the degradation rate is C = 350 hour^{-1}, find the time after which the ouptut radiant power will fall to half its initial value, assuming room temperature (25° C) operation.

[*9 marks*]