OLLSCOIL NA h-ÉIREANN, CORCAIGH
THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA h-OLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

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

OPTICAL ELECTRONICS (EE4007)

Prof. J. O'Reilly,
Prof. R. Yacamini,
Dr S. L. Prunty,
Dr A. P. Morrison.

3 HOURS

The use of approved calculators is permitted.

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

Physical Constants:
Free electron mass, $m_0 = 9 \times 10^{-31}$ kg
Planck's constant, $h = 6.624 \times 10^{-34}$ J s
Electronic charge, $q = 1.6 \times 10^{-19}$ C
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J K^{-1}
Room temperature = 300 K
Speed of light in free space = 3×10^{8} m s^{-1}

Questions follow overleaf/…

SECTION B

5. (a) When specifying a digital optical receiver's performance a common metric used is comparing the bit-error-rate (BER) with the received optical power. Draw a diagram that qualitatively describes the relationship between BER and received optical power. Label the main features on this diagram.

   (b) What is the maximum length a fibre system can have assuming zero dB link margin and no coupling loss if the receiver sensitivity is –32dBm, fibre attenuation is 0.18 dB/km and the input power is 3 mW?

   (c) A digital optical receiver is sensitive enough to detect 150 photons/bit at a data rate of 2.5Gb/s and a wavelength of 1.55μm. What is the average received optical power in Watts? How many photons per bit would be received if the wavelength is changed to 1.3μm and the data rate increased to 10Gb/s? (you may assume the received optical power is the same)

6. (a) Explain what is meant by the following:
   - (i) Link Margin
   - (ii) Brewster Angle
   - (iii) Refractive index
   - (iv) Critical angle
   - (v) Numerical aperture

   (b) Draw the simplified band-diagram representation of a single quantum well, separate confinement heterostructure laser diode (SQW-SCH LD). Label each layer. (Hint: show bandgap for each layer, full credit for naming appropriate materials for each layer in the laser you choose)

   (c) Draw the light power versus current characteristic for both a Light Emitting Diode and a Laser Diode. Explain the fundamental difference between the two characteristics.

   (d) A 150 Å quantum well is formed from two materials having bandgap energies of 2.2 eV and 1.65 eV respectively. The ratio of the conduction band offset to the valence band offset for these materials is $\Delta E_c : \Delta E_v = 0.6 : 0.4$. The electron effective mass in the quantum well is 0.11 m_0, where m_0 is the free electron mass. If the valence band edge for the wider bandgap material is taken as the reference (zero) energy, at what energies do the quantised energy levels in the conduction band of the quantum well occur? How many discrete energy levels can be accommodated in the conduction band of this quantum well?

7. (a) Explain the term Noise Equivalent Power (NEP) with reference to semiconductor photodetectors.

   (b) Describe the process of impact ionization as applied to avalanche photodiodes. How does this provide internal optical gain?

   (c) A p-i-n photodiode has a NEP of 1.4×10^{-12} W/Hz$^{1/2}$ and a responsivity of 0.45 A/W at 632.8 nm. The bandwidth may be assumed to be 100 Hz. If this photodiode is illuminated by a HeNe laser emitting 3 mW of power, at what distance will the detector no longer be able to detect the laser radiation. (you may assume that the laser is perfectly collimated and completely focused onto the detector, also assume inverse square law for beam power.)

8. (a) List five differences between Light-emitting diodes (LEDs) and Laser diodes.

   (b) What peak emission wavelength is to be expected from an LED having an active region with a band-gap of 1.8 eV? Draw the spectral output if $\Delta\lambda$ = 20 nm.

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

   (d) A GaAs/AlGaAs LED has an activation barrier of energy E_d = 0.6 eV to long-term degradation. If the prefactor in the Arrhenius equation describing the degradation rate is C = 250 hour^{-1}, find the time after which the ouptut radiant power will fall to half its initial value, assuming room temperature operation.