UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: August 2014

Module Number: EE5317

Module Name: Sensors, Transducers and Measurement Techniques

[Three Hours]

[Answer **all questions**, each question carries 10 marks]

Q1 a) Short answer questions

i. At 0 Kelvin (K) what is the distribution of electrons and holes in an intrinsic semiconductor?

ii. At temperatures greater than 0 K, what is the distribution of electrons and holes in an intrinsic semiconductor?

iii. Which parameter describes the band structure of a semiconductor?

iv. Distinguish the difference between a direct gap and an indirect gap semiconductor.

v. What are the most important semiconductors for light emitting devices and how are they formed?

vi. Why are the binary and ternary nitrides unique?

vii. What is the relationship between band gap and the type of material?

viii. How can photons emitted through a process involving impurities have energy lower than the band gap of the semiconductor?

[4 Marks]

b) i. What are the two fundamental conservation laws that must be satisfied by any band to band transition?

ii. What are the conservation equations for a direct band-to-band transition with the absorption or emission of a photon?

iii. What are the conservation equations for an indirect band-to-band transition with the absorption or emission of a photon?

iv. Sketch diagrams to illustrate the spontaneous emission and stimulated emission processes for a direct gap semiconductor.

v. Which of these processes are employed in a LASER and a LED?

vi What does the acronyms LASER and LED stand for?

vii. State two main differences between the outputs of a LASER and a LED.
viii. Give the circuit symbol for these devices.

[4 Marks]

c) The absorption $\alpha(v)$ and gain $g(v)$ coefficients contributed by direct band-to-band transitions in a semiconductor at thermal equilibrium can be written as

$$g(v) = -\alpha(v) = \alpha_0(v) [\, fc(E) - fv(E)]$$

where $\alpha_0(v)$ is the intrinsic semiconductor absorption coefficient and fc and fv denotes the probability of occupying an energy state E in the conduction and valence bands respectively..

i. Explain the process described by this equation.

ii. What condition must this equation satisfy for a LASER and how is this condition achieved in practice?

[2 Marks]

Q2 a) i. Sketch the energy bands, excess carrier distribution, refractive index and optical field distribution profiles for a p-n homostructure in forward bias.

ii. Which is the main active region and which parameters determines this region for this structure.

iii. p-n homostructures have poor waveguiding capabilities. How is this homostructure modified to obtain a Double Heterostructure that has good waveguiding capability?

iv. Sketch the energy bands, excess carrier distribution, refractive index and optical field distribution profiles for a Double Heterostructure.

[3 Marks]

b) i. Sketch the cross-section of the structure of a LED and name its main components.

ii. Sketch the Light-Current (L-I) characteristics and the spectrum for a LED.

iii. Denote a suitable region for analog modulation in the L-I characteristics.

[3 Marks]

c) i. An edge-emitting laser requires optical feedback and optical gain for operation. Two laser designs that achieve this is the Fabry-Perot resonator laser and the Distributed Bragg Reflector (DBR) laser. Sketch the structure of these devices and indicate their main features.

ii. Sketch the L-I characteristics and the associated spectra for a single mode and multi mode laser.

iii. Why is there a threshold current in laser operation?

[4 Marks]

Q3 a) Following are some commonly used performance parameters of photodetectors. Define and briefly describe these parameters.

i. Spectral response
ii. Quantum efficiency
iii. Responsivity
iv. Noise Equivalent Power (NEP)
v. Detectivity
vi. Linearity and Dynamic Range (DR)
vii. Speed and frequency response

[5 Marks]

b) i. Explain why the active region of a p-n homojuntion photodetector is only the depletion layer and the diffusion region.

ii. The p-n junction photodiode has unity gain with the external signal current i_s equal to the photo current generated by the incident optical power. When a bias voltage is applied to the photodiode give the equation for the total current of the photodiode?

iii. Sketch the I-V photodiode characteristics for varying optical power..

iv. Denote the two modes of operation in the I-V characteristics and suggest suitable electronic circuits to obtain an output voltage proportional to the incident optical power.

[5 Marks]

Q4 a) i. How does noise appear in a signal?

ii. If a signal has a value s, what is its mean value?

iii. How is noise s_n being a random variable defined?

iv. What is the mean value of s_n?

v. What is the mean square value of s_n?

vi. Define the root mean square value rms(s_n) of noise?

vii. Why is noise measured by rms(s_n)?

viii. Define signal to Noise Ratio (SNR).

ix. How is SNR normally expressed?

x. State the sources of noise in a photodetector.

[5 Marks]

b) i. Compare negative feedback and positive feedback amplifiers?

ii. What are the advantages of feedback amplifiers?

iii. An amplifier with negative feedback has a voltage gain of 100. It is found that without feedback, an input signal of 50 mV is required to produce a given output; whereas with feedback, the input signal must be 0.6 V for the same output. Calculate the value of voltage gain without feedback and the feedback ratio.

[5 Marks]

Q5. a) Briefly explain why a power amplifier is called a large signal amplifier?

[1 Mark]

b) What is the difference between a voltage amplifier and a power amplifier?

[1 Mark]

c) Explain how power amplifiers are classified with the help of suitable sketches.

[1 Mark]

d) Show that the maximum collector efficiency of a class B amplifier is 78.5 %

[2 Marks]

e) Give the advantages and disadvantages of the push-pull configuration in power amplifiers. [1 Mark]

f) A transistor rated for a maximum collector dissipation of 100 mW operates a single-ended class-A output stage from a 10 V supply. Calculate the following.

i. An approximate value for maximum undistorted a.c. output power

ii. The quiescent current

iii. The turns ratio of the output transformer, if the load resistor is 16Ω. Assume overall and collector efficiency are 0.5.

[4 Marks]