# UNIVERSITY OF RUHUNA

## Faculty of Engineering

End-Semester 5 Examination in Engineering: August 2015

**Module Number: EE5305** **Module Name: Sensors, Transducers and Measurement Techniques**

**[Three Hours]**

[Answer **all questions**, questions 1 and 2 carries 12.5 marks each, question 3 carries 5 marks and questions 4 and 5 carries 10 marks each]

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Q1

a) Si and GaAs are semiconductor materials that are used in manufacturing LEDs and Lasers.

i) Sketch the energy (E) vs the quantum mechanical wave number (k) diagrams for Si and GaAs respectively.

ii) Explain a band to band transition for Si and GaAs with reference to the diagrams in i). and their governing equations.

iii) Explain the transition processes associated with a LED and a Laser respectively.

iv) Give a practical definition of population inversion for a Laser.

[4 Marks]

b) i) Describe why the p region is the active region in a p-n homo junction LED.

ii) Sketch a suitable hetero structure for a Laser and define its different material properties.

iii) Sketch the excess carrier distribution, refractive index and optical field distribution profiles for the hetero structure in ii).

iv) Describe the main difference between the structures of a hetero structure Laser and of a Quantum Well Laser.

[5 Marks]

c) i) Sketch the basic structure of a LED and a Distributed Bragg Reflector (DBR) Laser respectively.

ii) Sketch the Light-Current characteristics of a LED and a Laser respectively.

iii) Sketch the spectral characteristics of a LED and a Laser respectively.

[3.5 Marks]

Q2

a) i) State the principle of operation of a photodetector.

ii) Define the two fundamental noise phenomena in a photodetector.

iii) Define the noise $s_n$ of a signal s.

iv) State two important characteristics of noise from the definition in iii).

v) Define the signal to noise ratio (SNR) of a signal. [3 Marks]

b) i) Justify that the photocurrent $i_s$ in a photodetecor that has unity gain and no noise is given by

$$i_s = \eta_e \, e \, P_s / h\nu$$

where $\eta_e$ is quantum efficiency, e is the electron charge, $P_s$ the input optical power and $h\nu$ the photon energy respectively.

ii) If the mean square noise in the incident photon number S and the generated charge carriers N are given by their mean values, formulate an expression for the shot noise of the photodetector from the expression for $i_s$ in i).

iii) Define the other sources of noise in a photodetector. [3.5 Marks]

c) i) Sketch the input optical power (Ps) vs the photocurrent ($i_s$) characteristic of a photodetector. [0.5 Marks]

ii) Define the following parameters with reference to the figure in i).

I. Responsivity Я
II. Noise Equivalent Power NEP
III. Detectivity D
IV. Dynamic Range DR
V. Bandwidth B

[2.5 Marks]

d) i) Sketch the current – voltage characteristics of a p-n junction photodiode for increasing optical input power.

ii) Formulate an equation that describes the characteristic in i).

iii) Identify the region of the characteristic used in the operation of a solar panel.

[3 Marks]

Q3

a) Synthesize schematic diagrams for the recording a hologram and the reconstruction of the hologram images. [2.5 Marks]

b) A schematic diagram of a radar system for tracking a target is shown in Figure Q3. The radar operates at a frequency $f_T = 5$ GHz. The target is travelling in a straight line towards the radar with a velocity $v_R = 100$ km/hour. The reflected echo from the target arrives at the radar at T = 66 µs. Calculate the

i) Distance to the target

ii) The Doppler shift

iii) The Doppler shift if the target is moving away from the radar

**Note:** the frequency of the echo $f_R$ as seen by the radar is given by

$$f_R = f_T \frac{1 + v_R/c}{1 - v_R/c}$$

where c is the speed of electromagnetic waves in air. [2.5 Marks]


Figure Q3

Q4

a) Explain the difference between a voltage and a power amplifier. [1 Mark]

b) State the differences between Class A, Class B, Class AB and Class C amplifiers.

[2 Marks]

c) A transformer coupled Audio power amplifier driving an 8 Ω speaker is shown in Figure Q4, along with the $V_{cc}$ and $I_c$ characteristics of the transistor used. If the circuit component values results in a dc base current of 6 mA and the input signal $v_{in}$ results in a peak base swing of 4 mA, determine

i) $V_{ce}$ max

ii) $V_{ce}$ min

iii) $I_c$ maximum and minimum values

iv) rms value of the load current

v) Efficiency of the amplifier circuit

[7 Marks]

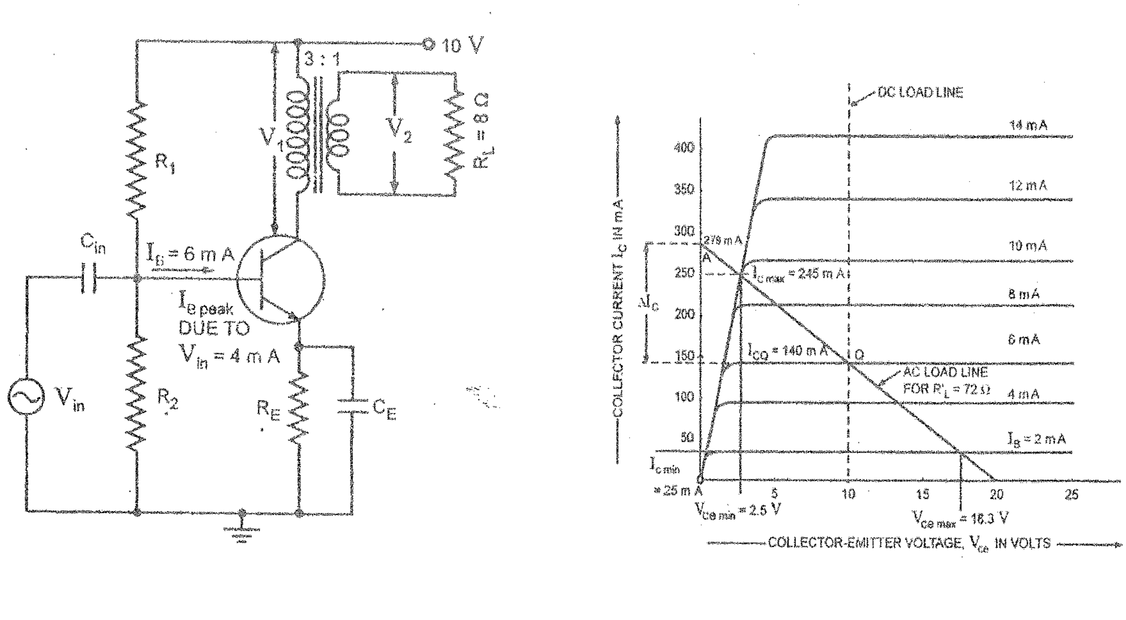


Figure Q4

Q5

a) i) Describe an active filter and a passive filter.

ii) Contrast between low pass, high pass, band pass and band stop filters.

iii) How do you recognize wideband and narrow band filters?

iv) Design a low pass filter having a cutoff frequency 2 kHz with a pass band gain of 2. Assume that capacitance of the capacitor is 0.001 μF.

[5 Marks]

b) i) What are the three main sources of experimental uncertainties (experimental errors)?

ii) A cart's kinetic energy is measured as $k = 4.58\ J \pm 2\%$. Rewrite this finding in terms of its absolute uncertainty.

iii) To determine the quantity $q = x^2y - xy^2$, a scientist measures x and y as follows.

$x = 3.0 \pm 0.1$ and $y = 2.0 \pm 0.1$

What is his answer for q and its uncertainty?

iv) A meter stick can be read to the nearest millimeter. A traveling microscope can be read to the nearest 0.1 mm. Suppose you want to measure a length of 2 cm with a precision of 1%. Can you do so with the meter stick? Is it possible to do so with the microscope?

[5 Marks]