UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: July 2016

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

[Three Hours]

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

Q1 a) i) Sketch the typical Energy (E) versus quantum mechanical wave number (k) diagrams for a direct and an indirect gap semiconductor.

ii) Describe the reason for the probability of band to band transition in a direct gap semiconductor being much greater than that of an indirect gap semiconductor.

iii) Describe the three band to band transitions in a direct gap semiconductor with the aid of diagrams.

[3.5 Marks]

b) The absorption and gain coefficients of a LASER are $\alpha(v)$ and $g(v)$ respectively, where v represent frequency. The valence and conduction bands are denoted by E_1 and E_2 respectively. The probability of electron transition from the valence band to the conduction band is $f_V(E_1)$ and from conduction to the valence band is $f_C(E_2)$.

i) Express $\alpha(v)$ and $g(v)$ in terms of $f_V(E_1)$ and $f_C(E_2)$ taking the proportionality constant as α_0.

ii) State the relation between $\alpha(v)$ and $g(v)$ for charge carriers in equilibrium.

iii) Explain the conditions necessary for population inversion for a LASER .

[3 Marks]

c) i) Describe the active region in a LED homojunction.

ii) Sketch the energy band diagram, carrier concentration, refractive index profile and the optical field of a p-n homojunction of a LED.

iii) Sketch the energy band diagram, carrier concentration, refractive index profile and the optical field of the semiconductor structure for a double heterostructure of a LASER.

[3.5 Marks]

Q2 a) i) Sketch the basic structure of a LED and label the component parts.

ii) I. Sketch the typical Light current (L – I) characteristic of a LED and its frequency response.

II. Identify the linear response region of the characteristic and explain how direct current modulation can be achieved in this region.

iii) The output optical power of the LED in response to input current modulation can be expressed as

$$P(t) = P_0 + P_1(t) = P_0 \left[1 + |r| \cos(\Omega t - \varphi) \right]$$

I. Explain the different terms in the equation.

II. State the semiconductor parameter that determines the maximum modulation speed of a LED.

[5 Marks]

b) i) State the general conditions for a LASER to oscillate at a particular frequency.

ii) Name the corresponding condition in Electronics.

iii) Describe the reason for having a resonant cavity for optical feedback in a LASER.

iv) Sketch the structures of an edge emitting and a surface emitting LASER based on Bragg reflectors.

v) Explain the reason for the high modulation speed of a LASER as compared to a LED.

[5 Marks]

Q3 a) i) State and explain the origin of the two fundamental noise phenomena in a photodetector.

ii) Define the noise s_n of a signal s.

iii) State two important characteristics of the noise s_n and their significance in signal processing.

[2 Marks]

b) i) Show that the photocurrent i_s in a photodetector that has unity gain and no noise is given by

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

where η_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 show that the expression for the shot noise of the photodetector is given by

$$\overline{i_{n,sh}^{\,2}} = 2\eta_e e^2 B \overline{P_s} / h\nu$$

where the bar indicates mean values.

Hint: Use the expressions derived in i)

[2.5 Marks]

c) i) Define the Noise Equivalent Power (NEP) and the responsivity Я of a photodetector.

ii) Show that NEP = rms(i_n) / Я

where i_n is the total noise current in the photodetector.

iii) Sketch the input optical power (Ps) vs the photocurrent (i_s) characteristic of a photodetector and define the Dynamic Range (DR).

[2.5 Marks]

d) i) Describe the active region of a p-n junction photodiode.

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

iii) Design a circuit to operate the photodiode in the photoconductive (Reverse Bias) region and explain its operation.

[3 Marks]

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) State what you understand by the term "negative feedback" in an amplifier?

[1 Mark]

d) A transformer coupled class A audio power amplifier driving an 8 Ω speaker is shown in Figure Q4 a). The transistor output characteristics are shown in Figure Q4 b). If the circuit component values result in a dc base current of 6 mA and the input signal V_{in} result in a peak base swing of 4 mA , determine

i) the maximum and the minimum values of V_{ce}

[1 Mark]

ii) the maximum and the minimum values of I_c

[1 Mark]

iii) the rms value of the load current and the load voltage

[1 Mark]

iv) the power dissipated by the transistor

[1 Mark]

v) The efficiency of the amplifier circuit

[2 Marks]

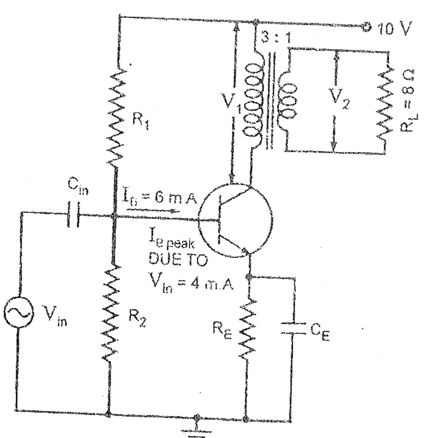

Figure Q4 a)

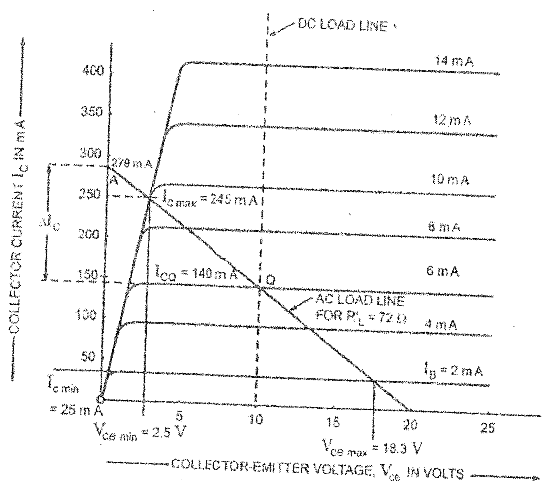

Figure Q4 b)

Q5 a) Evalulate the acceleration of gravity g, using a simple pendulum. The period of such a pendulum is known to be

$$T = 2\pi\sqrt{(l/g)}$$

where l is the length of the pendulum.

Measured values are $l = 92.95 \pm 0.1$cm, $T = 1.936 \pm 0.004$s

[2 Marks]

b) Following measurements of the length l and width b of a rectangle were made by a Vernier Caliper.

Table: Vernier Caliper measurements.

l(mm)	b(mm)
24.25	50.36
24.26	50.35
24.22	50.41
24.28	50.37
24.24	50.36
24.25	50.32
24.22	50.39
24.23	50.38
24.24	50.38
24.22	50.35

The area of the rectangle is defined as $A=l*b$. Considering the standard deviation of the mean (SDOM), estimate the error percentage when you compute the area(A).

[3 Marks]

c) A student, A, measures the voltage V [Volts] across a resistor 10 times for a constant current and obtains the values

V_A = 14.3, 15.4, 15.6, 15.2, 16.1, 16.8, 17.3, 16.5, 15.6, 14.7

Independently, another student, B, also measures the voltage V [Volts] across the same resistor 10 times for the same constant current and obtains the values

V_B = 13.1, 14.6, 15.3, 14.6, 15.4, 15.8, 16.9, 15.7, 14.4, 16.7

Assume that both the measurement sets are normally distributed.

i) Whose measurements are more precise? Justify your answer.

ii) Rewrite both students results in the standard form $x = x_{best} \pm \delta x$ Explain how you calculated the uncertainties.

[5 Marks]