UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: August 2018

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

[Three Hours]

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

Q1 a) Figure Q1 a) shows three transmitters used for signal generation and their operating environment.

i) Explain giving reasons which of these can/ cannot generate an acoustic wave.

ii) State the type of acoustic waves generated in part i).

iii) State the sound speed and the frequency range for acoustic wave generation at audible frequencies.

[2 Marks]

b) i) State the piezoelectric direct and converse effects.

ii) A piezoelectric ceramic disc material in its normal form is not piezoelectric. Explain why and the process to make the disc piezoelectric.

iii) Figure Q1 b) iii) shows the structure and dimensions of a piezoelectric disc and a cylinder. State the resonant frequencies of the two structures.

iv) Reproduce the electrical impedance characteristics and the equivalent circuit for a piezoelectric disc and state the resonance frequency of the equivalent circuit.

[4 Marks]

c) Figure Q1 c) shows a single transducer and a transducer array used in a Bathymetric Sonar System. Explain the function of the two transducer devices and their application.

[2 Marks]

d) A 1 MHz ultrasonic wave is incident on a solid surface from water at an incident angle θ_i. The density and sound speeds in water are ρ_1 and V_{c1} respectively and in the solid ρ_2, V_{c2} and V_{s2} respectively.

i) Sketch the reflection and transmission directions and define their angles for this arrangement.

ii) If the ultrasonic wave from water is now incident normal to the solid surface, define the reflection and transmission coefficients at the water/ solid interface.

[2 Marks]

Q2 a) With the aid of Energy-Wavevector diagrams, explain the difference between a direct gap semiconductor and an indirect gap semiconductor.

[2 Marks]

b) Sketch the three band to band transitions for a direct gap semiconductor.

[1 Mark]

c) State the relevant transitions for a direct gap semiconductor for a Light Emitting Diode (LED).

[1 Mark]

d) A PN homo-structure is normally used in constructing a LED.

i) Describe the active region in a LED PN homo-structure under forward bias.
ii) Sketch the Energy Band diagram, the excess carrier distribution, the refractive index profile and the optical field concentration for a LED PN homo-structure under forward bias.
iii) Sketch the characteristics for a LED and denote the modulation region.

[6 Marks]

Q3 a) The absorption and gain coefficients contributed by direct band-to-band transitions in a semiconductor are $\alpha(v)$ and $g(v)$ respectively.

i) State the relation between the coefficients at equilibrium.
ii) Express the coefficient $g(v)$ in terms of a constant $\alpha_0(v)$ and the probability of occupancy of states.
iii) Hence, explain the condition for Population Inversion for a LASER.

[2 Marks]

b) i) State and define the general criterion for a system to oscillate.
ii) State two properties of a LASER that realize this criterion.
iii) State the two hetero-structures suitable for a LASER.
iv) Sketch the Energy Band diagram, the excess carrier distribution, the refractive index profile and the optical field concentration for a LASER hetero-structure.

[4 Marks]

c) i) Sketch and label the components of a Fabry-Perot LASER and a Distributed Bragg Reflector (DBR) edge emitting LASER.
ii) Sketch the typical characteristics for a single and a multimode LASER and identify the modulation region.
iii) State the main reason for the high switching speeds of LASERs as compared to LEDs.

[4 Marks]

Q4 a) i) Define the mean value of a signal s.
ii) Define the noise s_n of a signal s.
iii) Define how noise is calculated.
iv) Define the Signal to Noise Ratio (SNR).

[2 Marks]

b) i) For a photodetector without noise, show that the photocurrent i_{ph} is given by the equations,

$$i_{ph} = e\,N/T = 2eBN = \eta_e\, e\, P_s\,/\,h\nu$$

Note: Define the parameters in the equation.

ii) If noise in the photon number fluctuation is given by $\overline{S}$ and the mean square noise in the number of photogenerated carriers is given by $\overline{N}$, calculate the mean square current fluctuations for the shot noise of a photodetector that receives an optical power P_s from an input optical signal.
[Hint: Calculate the expression for $\overline{i_{n,sh}{}^2}$]

[3 Marks]

c) Sketch a typical input optical power vs output photocurrent characteristics for a photodetector and define the following in the sketch,

i) Noise Equivalent Power (NEP)
ii) Dynamic Range (DR)
iii) Responsivity (Я)

[2 Marks]

d) i) Show the active region for a PN junction photodetector with the aid of the Energy Band diagram.

ii) Sketch the characteristics for a PN junction photodetector and define the regions of operations and the equivalent circuit representation.

[3 Marks]

Q5 a) Explain the difference between a voltage amplifier and a power amplifier.

[1 Mark]

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

[1 Mark]

c) A power amplifier working in Class A has a transformer as the load. If the transformer has a turns ratio of 10 and the secondary load is 100 Ω, find the maximum ac power output for a zero signal current of 0.1 A.

[2 Marks]

d) Explain the use of feedback in an amplifier?

[1 Mark]

e) What are the advantages of negative feedback in amplifiers?

[1 Mark]

f) An amplifier without feedback gives a fundamental output of 36 V with 7 % second harmonic distortion. The input voltage to the amplifier is 0.028 V,

i) What is the output voltage, if 1.2 % of the output is fed back into the input in negative voltage series feedback?

[2 Marks]

ii) What is the input voltage, if the fundamental output is maintained at 36 V but the second harmonic distortion is reduced to 1 %?

[2 Marks]

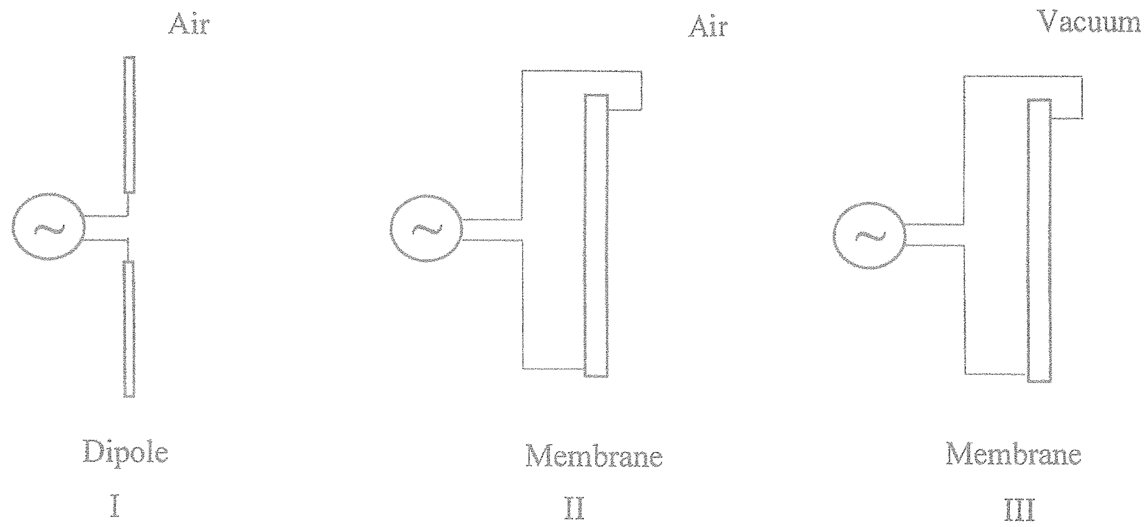

Figure Q1 a)

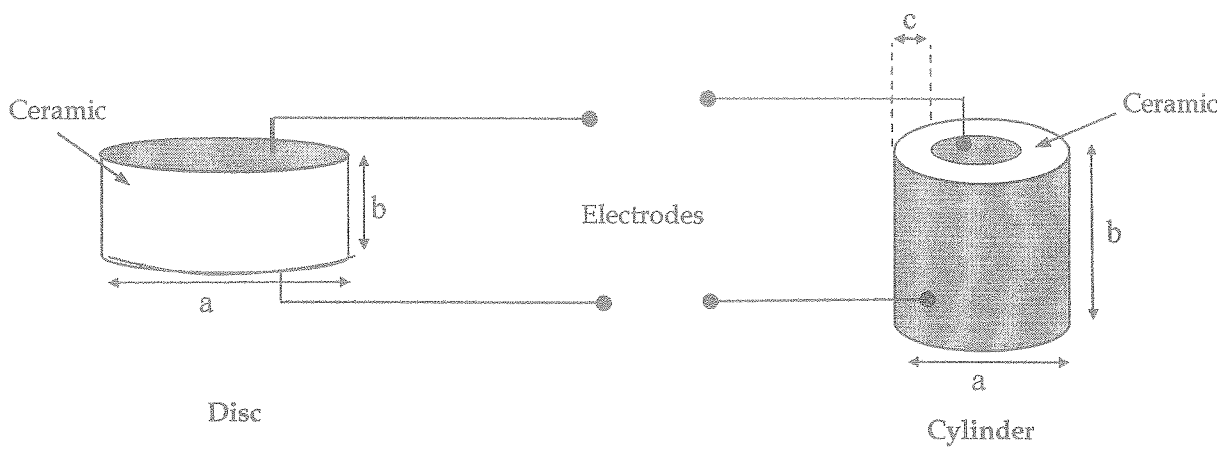

Figure Q1 b) iii)

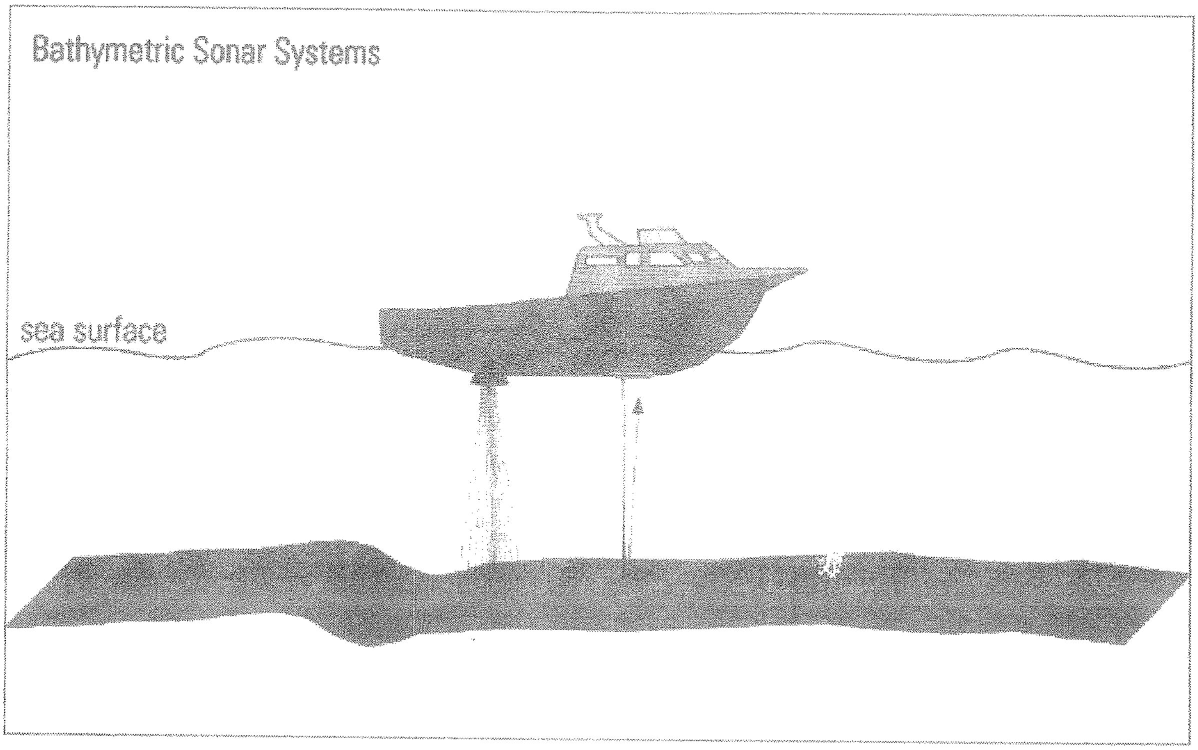

Figure Q1 c)