MACHAKOS UNIVERSITY

University Examinations 2017/2018

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FOURTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 414: INSTRUMENTATION

DATE: 18/12/2017 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS

Attempt Question ONE and any other TWO questions.

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Differentiate between Measurement and Instrumentation as used in practice and list the four main functions performed by Instrumentation and Measurement Systems. (4 marks)

b) Differentiate between sensitivity and resolution (2 marks)

c) The output of an LVDT is connected to a $10V$ voltmeter through an amplifier with a gain of 250. The voltmeter scale has 100divisions and the scale can be read up to $1/5^{th}$ of a division. An output of $2mV$appears across the terminals of the LVDT, when core is displaced through a $0.5mm$. Determine the following:

   i. Sensitivity of the measuring system
   ii. Resolution of instrument (4 marks)

d) With aid of a suitable diagram, explain the construction and operation of the weighted resistor digital to analogue converter (4 marks)

e) Consider an 8-switch D/A converter that employs a reference voltage of 5.0 V. The unit of ladder resistance is $R = 5\ k\Omega$ and the feedback resistor is $15\ k\Omega$. The maximum output voltage is 14.9414 V, and the value of the LSB is approximately 0.0586 V. If the switch settings correspond to the binary number 01101011, determine the D/A output voltage

(4 marks)

f) Instruments are normally calibrated and their characteristics defined for particular standard ambient conditions. What procedures are normally taken to avoid measurement errors when using instruments that are subjected to changing ambient conditions (4 marks)

g) Consider a strain gauge made up of a circular wire as shown in Figure Q1g. The dimensions are length L, *area* A and diameter D subjected to change by being strained. Let the wire resistivity be ρ, the resistance of the strain wire be R , ε the strain and v is the Poisson ratio. Derive the expression for the Gauge Factor (G_f) in terms of v, ρ and ε (6 marks)

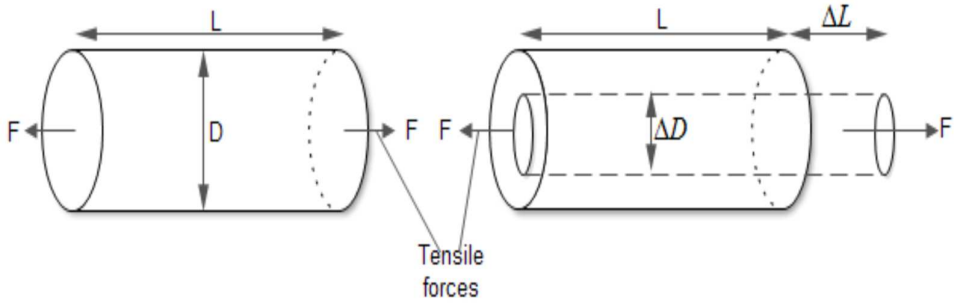

Figure Q1g.

h) A strain gauge has an associated gauge factor of 1.90. Assuming the resistivity does not change, what is the value of Poisson's ratio? (2 marks)

QUESTION TWO (20 MARKS)

a) Explain the construction and principle of operation of the following temperature transducers
   i. Thermistor
   ii. Resistance temperature devices (4 marks)

b) The data sheet for a particular thermistor gives the following information: resistance at 15°C of 1255.8 Ω, and resistance at 35°C of 800 Ω. Determine
   i. The coefficient β
   ii. The temperature for a resistance of 1100 Ω (4 marks)

c) Light transducers are designed using photoelectric semiconductors. Explain the TWO categories of these semiconductors clearly stating devices that are developed in each category (6 marks)

d) The relationship between input signal V_i and output signal V_o is given by $V_i = V_o + C$ where C is a constant and represents a form of bias in the output signal. With aid of suitable circuit diagram, explain how this bias can be removed (6 marks)

QUESTION THREE (20 MARKS)

a) Explain the principle of operation and typical applications of the following sensors
   i. Piezoelectric sensor
   ii. Hall effect sensors
   iii. Capacitive sensors
   iv. Magnetic reluctance
   v. Optic sensors (10 marks)

b) Define the Instrumentation Amplifier (2 marks)

c) By referring to the circuit diagram of an instrumentation amplifier shown in Figure.Q2d), redraw the diagram by labelling appropriately the three op-amps as $A_1, A_2,$ and A_3 ,the resistors as R_1, R_2, R_3 and R_4 , the input signal to A_1 as V_1 and to A_2 as V_2 and finally the output from A_3 as V_{OUT}. Hence, show that the general expression for overall voltage gain of the instrumentation amplifier circuit is given as: (6 marks)

$$V_{out} = (V_2 - V_1)\left[1 + \frac{2R_2}{R_1}\right]\left(\frac{R_4}{R_3}\right)$$

d) Given that, when $R_1 = 1k, R_2 = 2.5k, R_3 = 1k$, and $R_4 = 10k$, the output voltage , $V_{OUT} = 6V$, and when R_2 and R_4 are changed to $1.5k$ and $5k$ respectiveley with the other resistor values unchanged, $V_{OUT} = 4V$,determine the values of V_1 and V_2. (2 marks)

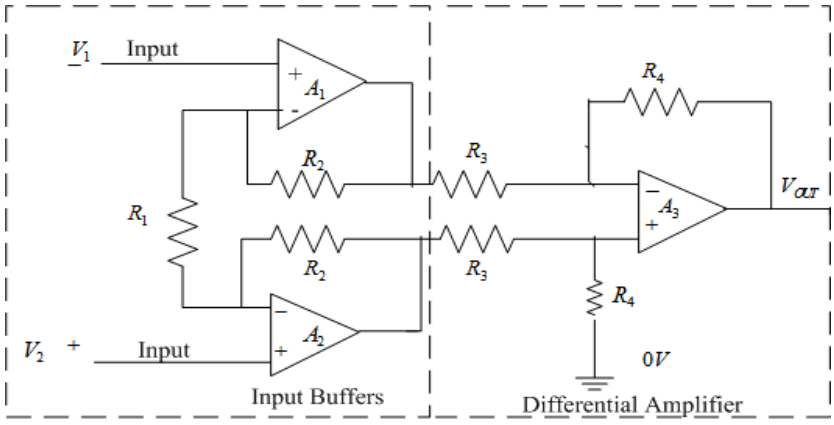

Figure.Q2d). Instrumentation Amplifier

QUESTION FOUR (20 MARKS)

a) Explain the construction and principle of operation of
   i. Load cell (3 marks)
   ii. Resistance strain gauge (3 marks)

b) Creep is one of the major challenges that face the use of load cells as force transducers. Explain this phenomena stating clearly how it can be mitigated (2 marks)

c) A load cell calibrated at a temperature of 20^0C has its output/input characteristics as shown in Table Q4c (i) while when it is used in an environment of 40^0C, its characteristics change to those presented in Table Q4 c (ii).

TableQ4 c (i)

Load in kN	0.00	0.40	0.80	1.2	1.6	2.0
Deflection of meter in mm	0	10	20	30	40	50

TableQ4 c (ii)

Load in kN	0.00	0.40	0.80	1.2	1.6	2.0
Deflection of meter in mm	3	14	25	36	47	58

   i. Determine (a) zero drift, (b) sensitivity drift, and (c) sensitivity drift per $°C$ change in ambient temperature. (3 marks)
   ii. If $0.5mm$ of scale division can be read with a fair degree of certainty, then determine the resolution of the instrument in both cases, i.e., at 20^0C and40^0C. (3 marks)

d) With aid of suitable circuit diagrams, explain the following analog signal processing techniques
   i. Signal linearization
   ii. Signal integration (6 marks)

QUESTION FIVE (20 MARKS)

a) With aid of suitable diagrams, explain the construction and principle of operation of the following signal conditioning circuits
   i. Voltage to frequency converter
   ii. Frequency to voltage converter (6 marks)

b) In the circuit of Figure. Q5b, the voltage across AB is measured by a voltmeter whose internal resistance is $9500ohm$. Given that:

$$R_1 = 400\Omega, R_2 = 600\Omega, R_3 = 1000\Omega, R_4 = 500\Omega \text{ and } R_5 = 1000\Omega$$

   i. Derive the expressions for the equivalent resistance across point CD and AB.

ii. What is the measurement error caused by the resistance of the measuring instrument? (4 marks)

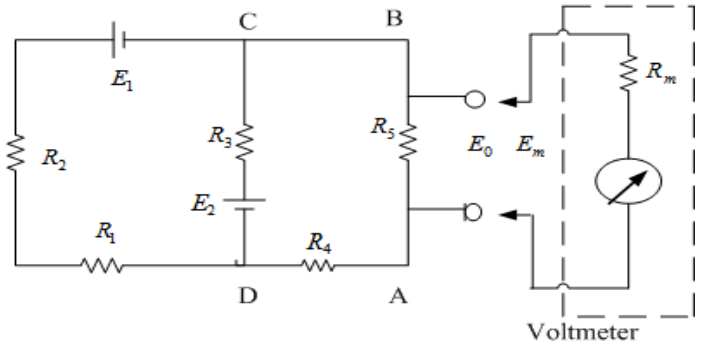

Figure.Q5b

c) A mercury-in-steel thermometer employs a Bourdon pressure gauge which has a range of $0 - 6.0MPa$ for the pointer rotation from $0\ to\ 270^0$. In the temperature calibration process, the pointer movement was set to 0^0 rotation at 0^0C and the instrument indicated 250^0 rotation corresponding to 200^0C. Determine:

i. The sensitivity of the instrument in $rad/^0C$. (2 marks)

ii. The error due to ambient temperature rise of 16^0C if the thermometer bulb has $8times$ that of combined volume of capillary and the Bourdon tube, and (2 marks)

iii. The error in the observed temperature values if the bulb is raised by $60cm$ from calibration elevation. (2 marks)

d) Explain any **TWO** sources of noise and any **TWO** techniques used in reduction of noise in instrumentation and measurement systems. (4 marks)