TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering and Technology
Department of Mechanical & Automotive Engineering
UNIVERSITY EXAMINATION FOR:
BSc. Mechanical Engineering
EMG 2505 : Measurement and Instrumentation
SUPPLEMENTARY EXAMINATION
TIME: 2 HOURS

Instruction to Candidates:

You should have the following for this examination

- *Answer booklet*
- *Non-Programmable scientific calculator*

This paper consists of **FIVE** questions. Attempt question **ONE** and any other **TWO** questions.

Maximum marks for each part of a question are as shown.

Do not write on the question paper.

Question ONE (Compulsory)

a. An instrumentation system is usually an assemblage of physical quantities. Using a block diagram identify and explain the main elements of an instrumentation system. **(6 marks)**

b. A bridge circuit, as shown in Figure Q1, is used to measure the value of the unknown resistance R_g of a strain gauge of nominal value 500 Ω. The output voltage measured across points DB in the bridge is measured by a voltmeter. Calculate the measurement sensitivity in volts per ohm change in R_g **(8 marks)**

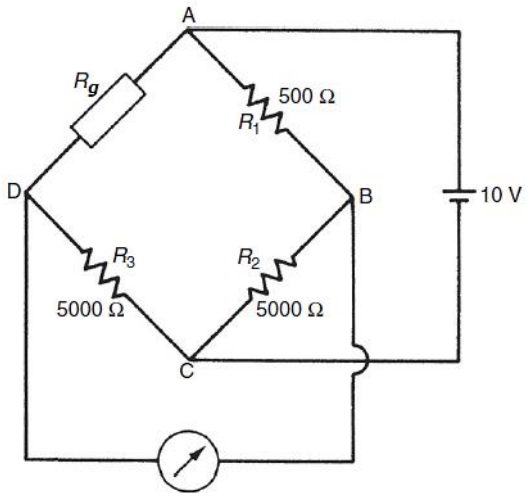

Figure Q1

c. A temperature measuring system incorporates a platinum resistance thermometer, a Wheatstone bridge, a voltage amplifier and a pen recorder. The individual sensitivities are as follows:

Transducer 0.35 Ohm/°C
Wheatstone bridge 0.01V/Ohm
Amplifier gain 100V/V
Pen recorder 0.1cm/V

Determine:

i. The overall system sensitivity
ii. The temperature changes corresponding to a recorder pen movement of 4cm **(6 marks)**

d. Differentiate between the following:
   i. Systematic errors and random errors
   ii. Accuracy and precision **(6 marks)**

e. Define calibration and explain its importance in a measurement system. **(4 marks)**

Question TWO

a. Briefly explain what a signal conditioning circuit is and state its importance in measurement systems. **(4 marks)**

b. A certain type of pressure transducer, designed to measure pressures in the range 0–10 bar, consists of a diaphragm with a strain gauge cemented to it to detect diaphragm deflections. The strain gauge has a nominal resistance of 120 Ω and forms one arm of a Wheatstone bridge circuit, with the other three arms each having a resistance of 120 Ω. Bridge output is measured by an instrument whose input impedance can be assumed infinite. If, in order to limit heating effects, the maximum permissible gauge current is 30 mA, calculate the maximum permissible bridge excitation voltage.

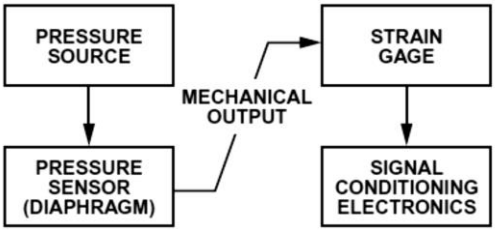

Figure Q2a

Figure Q2a shows block diagram of the instrumentation system. If the sensitivity of the strain gauge is 338 mΩ/bar and the maximum bridge excitation voltage is used, calculate the bridge output voltage when measuring a pressure of 10 bar. **(10 marks)**

c. An ac bridge is in balance with the following constants: arm AB, R = 200 Ω in series with L = 15.9 mH R; arm BC, R = 300 Ω in series with C = 0.265 μF; arm CD, unknown; arm DA, = 450 Ω. The oscillator frequency is 1 kHz. Find the constants of arm CD.

(6 marks)

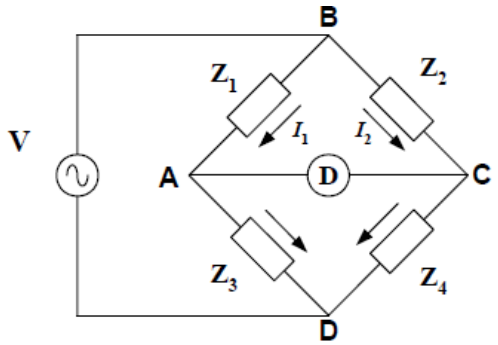

Figure Q2b

Question THREE

a. Distinguish between "sensing" and "transduction" in an instrumentation system.

(2 marks)

b. With the aid of constructional diagram, explain the principles of operation of the following transducers:

(i) Linear variable differential transformer (LVDT)

(ii) Variable capacitance displacement transducer **(8 marks)**

c. Consider the Maxwell bridge shown in Figure Q2, let the fixed-value bridge components have the following values: $R_3 = 5\Omega; C = 1mF$. Obtain the following:

i. Derive the expression used to find the unknown inductive impedance Z_u (L_u and R_u)

ii. The value of the unknown impedance (Lu, Ru) if $R_1 = 159\Omega$ and $R_2 = 10\Omega$ at balance.

iii. The Q factor for the unknown impedance at a supply frequency of 50 Hz.

(10 marks)

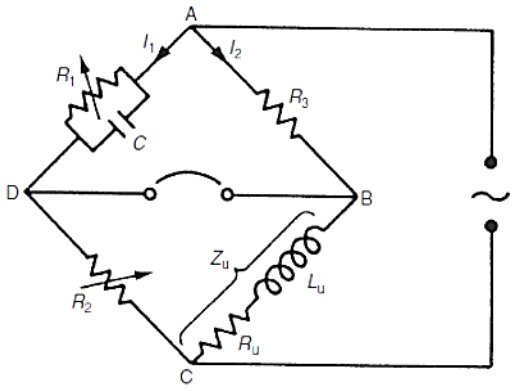

Figure Q3

Question FOUR

a. Explain the following systematic characteristics of a measurement system:
   i. Range
   ii. Precision
   iii. Sensitivity
   iv. Resolution (4 marks)

b. Many measuring systems can be represented by an equivalent system consisting of a spring, mass and damper as shown in Figure Q4

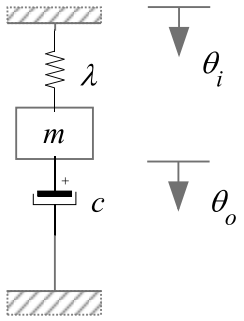

Figure Q4

Where,
λ is the spring stiffness (N/m)
C is the viscous damping coefficient (Ns/m)
m is the mass

If θ_i is the input displacement in meters and θ_o is the output displacement also in meters. Show that the device has a second order transfer function also determine the damping ratio, ζ and undamped natural frequency, ω_n. (8 marks)

c.
i. With the aid of a diagram explain the principles of operation of an X-Y recorder.
ii. State any FOUR common applications of an X-Y recorder. (8 marks)

Question FIVE

a. The differential equation describing a mercury-in-glass thermometer is given below:

$$7\frac{d\theta_o}{dt} + 2\theta_o = 2\theta_i$$

Where θ_o is the height of the mercury column in meters and θ_i is the input temperature in ^{0}C.

i. Determine the time constant and static sensitivity of the thermometer.
ii. If the thermometer is quickly taken from a temperature of 0 ^{o}C to water bath at 100 ^{o}C. What temperature will be indicated after 1.5 s ?

(5 marks)

b. Figure Q5 shows a non-inverting voltage feedback circuit configuration, given $A_o = 100000$, $r_i = 2M\Omega$, $r_o = 75\Omega$, $R_1 = 100\Omega$ and $R_F = 100k\Omega$, determine the:

i. Feedback fraction
ii. Desensitivity
iii. Overall gain
iv. Closed loop input impedance
v. Closed loop output impedance. **(10 marks)**

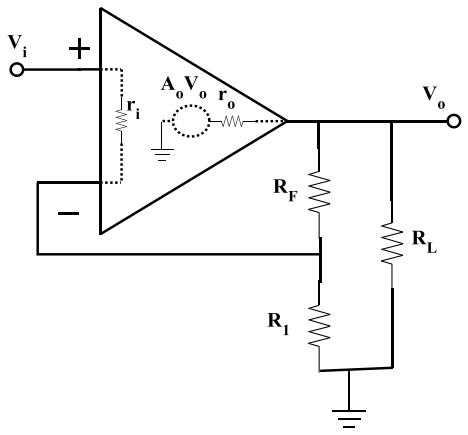

Figure Q 5

a. With the aid of a diagram explain the principles of operation of an X-Y recorder.

(5 marks)