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
SERIES: SEPTEMBER 2018
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 single strain gauge having resistance of 120 Ohm is mounted on a steel cantilever beam at a distance of 0.15 m from the free end. An unkown force F applied at the free end produces a deflection of 12.7 mm of the free end. The change in gauge resistance is found to be 0.152 Ohm. The beam is 0.25 m long with a width of 20 mm and a depth of 3 mm. The Young's modulus for steel is 200 GN/m². Calculate the gauge factor, G_f. (10 Marks)

Given,

Moment of inertia of beam,

$$I = \frac{1}{12}(bd^3)$$

Deflection of a cantilever beam,

$$F = \frac{3EIx}{l^3}$$

c. Consider a resistance Wheatstone bridge circuit made up of four resistors as shown in Figure Q1. If two resistor values change from balance condition to the following values $(R_1 + \Delta R_1)$ and $(R_2 + \Delta R_2)$. Determine the expression for the output voltage v_o in terms of the excitation voltage v_i and resistance values. (4 marks)

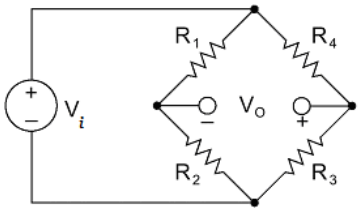

Figure Q1

d. A single 100 Ohm resistance strain gauge, having a gauge factor of 2 is mounted on a steel bar and is connected into a symmetrical bridge circuit as shown in Figure Q1. When the steel bar is subjected to a tensile force, the output voltage of the unloaded bridge is 5mV. If the recommended operating current of the gauge is 15mA, determine:
   i. The mathematical expression showing the relationship between the detector current and the strain.
   ii. The value of the mechanical strain. (6 marks)

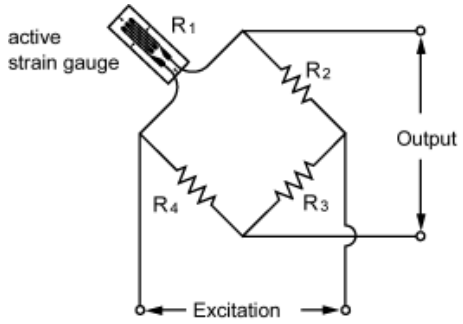

Figure Q1.

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. (6 marks)

b. Define the following terms as used in instrumentation amplifiers and identify their causes:
   i. Drift
   ii. Offset voltages (4 marks)

c.
   (i) Derive the expression for the output voltage of the amplifier shown in figure 1.

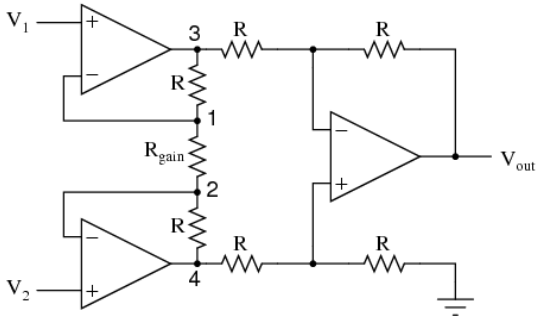

Figure 1

(ii) For the amplifier in (i), a common mode input signal of 0.5mV gives a common mode output of 0.05mV. Given that R =10MΩ and R_{gain} is adjusted to 10Ω. A right input from a transducer is 10μV. Determine:

i. The CMRR of the amplifier in dB.

ii. The measured signal at the output. (10 marks)

QUESTION THREE

a. A thermistor of resistance 1 kΩ, temperature co-efficient of resistance 4.5 per cent/°C and an internal temperature rise of 0.2°C/mW around 27°C is included in a d.c. bridge with three fixed resistors each of value of 1 kΩ. A d.c. amplifier of high input impedance is connected across the bridge output and an indicating device connected to the amplifier output.

i. Calculate the maximum voltage sensitivity of the bridge if the internal temperature rise is not to exceed 0.1°C

ii. Calculate the maximum amplifier drift, referred to the input that can be tolerated if the overall system accuracy is to be within ±2°C. (12 marks)

b. With the aid of a diagram explain the principles of operation of a cathode ray oscilloscope. (8 marks)

QUESTION FOUR

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

i. Resistive transducer (potentiometric type)

ii. Linear variable differential transformer (LVDT)

iii. Variable capacitance displacement transducer (12 marks)

b. Consider the Maxwell bridge shown in Figure Q4, 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.

(8 marks)

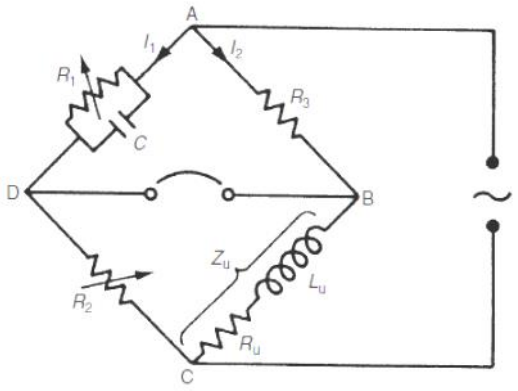

Figure Q4

QUESTION FIVE

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

b. With reference to operational amplifier define the following terms:
   i. Slew rate
   ii. Common mode rejection ratio
   iii. Offset voltage. (6 marks)

c. Figure Q 5 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)

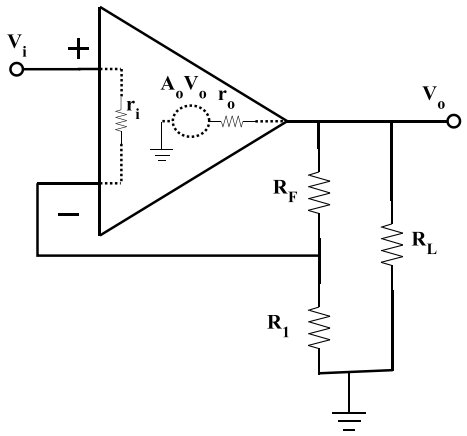

Figure Q 5