USE | 04/06/2018 | 09:00 | FNB GROUND FLOOR ANNEXE | EXAMS OFFICE ONLY

University of the Witwatersrand, Johannesburg

Course or topic No(s)	ELEN4006A
Course or topic name(s) Paper Number & Title	MEASUREMENT SYSTEMS
Examination to be held during month(s) of	JUNE 2018
Year of Study (Art & Science leave blank)	FOURTH
Degrees/Diplomas for which this course is prescribed (Bsc (Eng.) should indicate which branch)	BSc (Eng) ELECTRICAL ENGINEERING
Faculty/ies presenting candidates	ENGINEERING & BUILT ENVIRONMENT
Internal examiner(s) and telephone extension number(s)	Dr. LM Masisi x77212
External examiner(s)	Dr L Mthembu
Special materials required (graph/ music/ drawing paper/ maps/ diagrams/ tables/ computer cards, etc)	None

Time allowance

Course No	ELEN4006A	Hours	2

Instructions to candidates

Examination Type: Restricted Open Book (See Rule G13)
(Total Marks = 65: Full Marks = 60)
Extra material:
a) Log linear graph paper
b) Linear graph paper
See more instructions overleaf

Question 1

[20]

1.1 In designing a measurement system.

(a) What are the important specification parameters of the instrument to be considered? (List four parameters) Please explain or provide a short definition of each. (6)
(b) Should the measurement system be insensitive as possible to the operating environment? Why (explain your answer in (b))? (2)
(c) What are the environmental factors that could affect the measurement system if any? (2)

1.2 A thermocouple sensor has an electromotive force in μV.

$$E(T) = 38.74T + 3.319 \times 10^{-2}T^2 + 2.071 \times 10^{-4}T^3 - 2.195 \times 10^{-6}T^4$$

For the range 0 to 400 ^{0}C. For T = 0 ^{0}C, E (0) = 0 μV and E (400) = 20,869 μV.

(a) Calculate the expression for the ideal straight line relationship, E(T) = K.T. (2)
(b) Determine the sensitivity of the sensor (2)
(c) Obtain the maximum non-linearity of the system, as a function of the full scale (400 ^{0}C) (6)

Question 2

[20]

Two strain gauges are bonded onto a cantilever as shown in figure 1. Given that the gauges are placed halfway along the cantilever and the cantilever is subject to a downward force F. With the tabulated data:

Cantilever data		**Strain gauge data**	
Length	$l = 25cm$	Gauge factor	$G = 2.1$
Width	$w = 6cm$	Unstrained resistance	$R_0 = 120\Omega$
Thickness	$t = 3mm$		
Young's modulus	$E = 70 \times 10^9\ Pa$		

Note: Make sure to motivate all your designs clearly and list assumptions made

(a) Calculate the resistance of each strain gauge for F=0.5 N and F = 10 N. (2)
(b) Design a resistive deflection bridge suitable for force measurement in the interval in (a) (10)
(c) Design a first order filter to remove external high frequency noise and comment on your ADC Sampling frequency. (8)

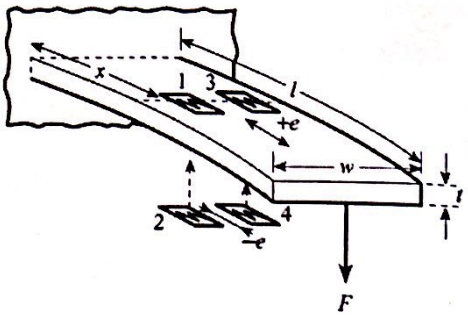

Figure 1: Strain gauges bonded onto a cantilever [J.P Bently, pp. 179-180]

Question 3 [25]

3.1 A balloon is equipped with temperature and altitude measuring instruments and has radio equipment that can transmit the output readings of these instruments back to ground. The balloon is initially anchored to the ground with the instrument output readings in steady state. The altitude-measuring instrument is approximately zero order and the temperature transducer first order with a time constant of 15 seconds. The temperature on the ground, T_0, is 10 ^{0}C and the temperature T_x at an altitude of x metres is given by the relation: $T_x = T_0 - 0.01x$.

(a) If the balloon is released at time zero, and thereafter rises upwards at a velocity of 5 metres/second draw a table showing the temperature and altitude measurements reported at intervals of 10 seconds over the first 50 seconds of travel. Show also in the table the error in each temperature reading. (12)

(b) What temperature does the balloon report at an altitude of 5000 metres? Please comment on the error progression as the altitude increases. (2)

3.2 Figure 2 shows a configuration of a differential amplifier. Two amplifiers are available one with $A_d = 200$ and CMRR = 80dB and the other with $A_d = 200$ but with a CMRR of 60dB. If the differential input to the amplifier is 5 mV (i.e. V_{AB}=V_d = 5mV)

(a) Which amplifier should the designer use? Please provide a reason by means of analysis of both the circuits. (8)

(b) What could be done to reduce the effects of CMRR, list at least two possible ways and state their challenges if any? (3)

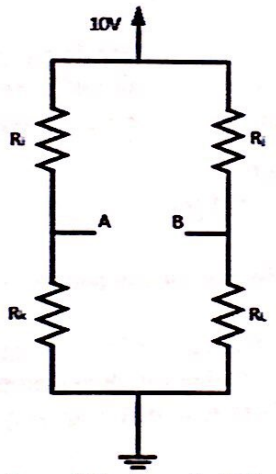

Figure 2: Signal conditioning of a Wheatstone bridge

(Total 65 Marks)