UNIVERSITY OF SWAZILAND
MAIN EXAMINATION, NOVEMBER/DECEMBER 2017

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER:	**INSTRUMENTATION SYSTEMS**
COURSE NUMBER:	**EE521**
TIME ALLOWED:	**THREE HOURS**

INSTRUCTIONS:

1. There are five questions in this paper. **Answer any FOUR questions.**
2. Each question carries 25 marks.
3. Marks for different sections are shown on the right hand margin.
4. Show the steps clearly in all your calculations including any assumptions made.

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THIS PAPER HAS SIX(6) PAGES INCLUDING THIS PAGE

QUESTION 1 ***(25 marks)***

(a) Distinguish between the following terms as used in measurements:

(i) Active and passive transducers. *(2 marks)*

(ii) Echo and Doppler ultrasound. *(2 marks)*

(iii) Sensitivity and resolution. *(2 marks)*

(iv) Frost point and dew point. *(2 marks)*

(v) Gauge pressure and absolute pressure. *(2 marks)*

(b) The voltage across a resistive sensor R_2 is measured using the simple voltage divider circuit shown in Fig Q2.b. The true voltage V_{oT} across the sensor is obtained only when a voltmeter of infinite input impedance is used. However, in practice, a voltmeter of finite input impedance R_m is used, and a measured voltage V_{om} is obtained.

(i) Show that the ratio of measured voltage V_{om} to the true voltage V_{oT} is given by

$$\frac{V_{om}}{V_{oT}} = \frac{R_m(R_1 + R_2)}{R_1(R_1 + R_m) + R_2 R_m}$$ *(6 marks)*

(ii) If $R_1 = R_2 = 480\ \Omega$ and $R_m = 10\ \text{k}\Omega$, find the % error in the measured value. *(5 marks)*

(iii) With the aid of a circuit diagram, show how this circuit may be modified so that the meter indicates a value as close as possible to the true voltage. *(4 marks)*

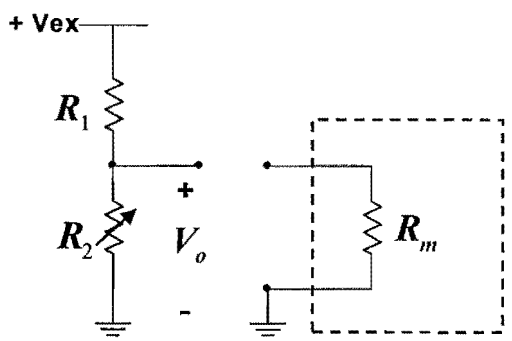

Fig. Q2.b

QUESTION 2 *(25 marks)*

(a) What is the average velocity in a pipe, if the diameter of the pipe is 0.82 cm and the flow rate is 90 cm^3/s? *(3 marks)*

(b) **(i)** A quartz piezoelectric material has rectangular dimensions 5 mm x 5 mm x 1.5 mm), and charge sensitivity of 155 pF/N. The modulus of elasticity the material is $E = 12 \times 10^{10}$ Pa. If a compressive force of 10 N is applied normal to the 5 mm x 5 mm face of the quartz, determine:

i. The resulting strain. *(2 marks)*

ii. The charge generated. *(2 marks)*

iii. The capacitance. *(2 marks)*

(ii) Explain the following in connection with use of quartz materials:

(i) Why they are not normally used in static measurements. *(2 marks)*

(ii) How they can be used in measurement of acceleration. *(4 marks)*

(c) A solid state pressure sensor with sensitivity 25 mV/Pa is fixed to the bottom of a tank to measure the level of liquid in the tank. The liquid has a density of 1.3×10^3 kg/m^3 and the level of liquid in the tank varies from 0.0 (empty) to 2.0 m (full).

(i) Specify the range of the pressure sensor required. *(6 marks)*

(ii) What is the sensor output when the tank is full? *(2 marks)*

(iii) What is the sensitivity of the sensor per cm of depth? *(2 marks)*

QUESTION 3 *(25 marks)*

(a) **(i)** Briefly describe the construction and principles of operation of a Linear Variable Differential Transformer (LVDT) as a displacement and position sensor. *(8 marks)*

(ii) The output of an LVDT is connected, through an amplifier whose amplification factor is 120, to a 3-and-half digit voltmeter on its 2-V range. If an output of 6 mV appears at the LVDT output when a displacement of 0.5 mm is made, determine:

i. The sensitivity of the whole instrument. *(3 marks)*

ii. The resolution of the instrument in mm. *(3 marks)*

iii. The displacement when the voltmeter reads 1.652 V. *(3 marks)*

(b) A sensor output signal range is 25 mV to 250 mV. Develop a signal conditioning circuit to feed this signal to an ADC input which has a 0 to 5 V input signal range. The circuit should have high input impedance so as not to load the sensor. *(8 marks)*

QUESTION 4 ***(25 marks)***

(a) What is the change in light intensity when the distance from a light source is increased from 10 m to 27 m? *(3 marks)*

(b) A light beam directed to a CdS photoconductive cell is used for counting objects interrupting the beam as they pass across the beam. The cell has a dark resistance of 120 kΩ and a resistance of 33 kΩ when in the light beam. The cell has a first order response with time constant of 75 ms.

(i) Design a circuit which alters the state of an analogue comparator within 12 ms of the interruption of the light beam. *(8 marks)*

(ii) Estimate, with reasons, the maximum number of objects which this system can count every minute. *(2 marks)*

(c) A strain gauge of a nominal resistance $R = 350\ \Omega$ and gauge factor $K = 2.1$ is used to measure stresses of up to 200 MPa in a material which has modulus of elasticity $E = 250$ GPa.

(i) What is the expected maximum change in strain gauge resistance? *(5 marks)*

(ii) Develop a circuit which would enable this strain gauge to give an output voltage from 0 V (with no stress) up to 1.5 V when full stress is applied. *(7 marks)*

QUESTION 5 ***(25 marks)***

(a) A fourth order equal-component Sallen-Key lowpass filter with a cut-off frequency of **620 Hz** is required for anti-aliasing.

(i) What is meant by anti-aliasing? *(2 marks)*

(ii) Draw a circuit diagram of the filter. *(2 marks)*

(iii) Given that a 4th order Sallen-Key **equal-component lowpass filter** needs gain values of $G = 1.152$ **and** 2.235, complete the design by working out the values of all the components in the circuit. *(9 marks)*

(b) Design a circuit to transmit a 0 to 3 V analogue signal over a 4 mA to 20 mA current transmission loop. Assume that load is floating and that amplifiers saturate at ±10 V. What are limits of the load resistance at the receiver? *(12 marks)*

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