# MACHAKOS UNIVERSITY

**University Examinations 2022/2023**

**SCHOOL OF PURE AND APPLIED SCIENCES**
**DEPARTMENT OF PHYSICAL SCIENCES**

**FOURTH YEAR FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)**

**SPH 410: SENSORS AND TRANSDUCERS**

**DATE:** **TIME:**

**INSTRUCTIONS:**

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

**QUESTION ONE (30 Marks)**

**a)** Distinguish between the following terminologies in sensors and transducers

i. Nonlinearity and Hysteresis (2 marks)

ii. Dead band and Resolution (2 marks)

**b)** List four main classifications of sensors and transducers. (4 marks)

**c)** Describe with suitable diagrams the working principle of strain gauges. Describe the terms Poisson's ratio and gauge factor. (5 marks)

**d)** For a certain thermistor $\beta = 3100$ K and its resistance at 20°C is known to be 1050 Ω.The thermistor is used for temperature measurement and the resistance measured is 2300 Ω. Calculate the measured temperature if the temperature resistance characteristics of the thermistor is given by

$$R = R_0 \exp\left\{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right\}$$

Where β is a thermistor constant (5 marks)

**e)** Explain with aid of diagrams the working principle of the following devices

i. Capacitive type proximity sensor. (3 marks)

ii. Hall-effect transducer. (3 marks)

**f)** Distinguish between active and passive electrical transducers and give some examples of them. (6 marks)

**QUESTION TWO (20 Marks)**

**a)** Highlight three main advantages of a sensor technology system (3 marks)

**b)** Calibration of a transducer instrument gave the following data. Determine the maximum hysteresis error as a percentage of the full-scale range. (6 marks)

Increasing input:

| | | | | | |
|---|---|---|---|---|---|
| Standard mV | 0 | 1.0 | 2.0 | 3.0 | 4.0 |
| Voltmeter mV | 0 | 1.0 | 1.9 | 2.9 | 4.0 |

Decreasing input:

| | | | | | |
|---|---|---|---|---|---|
| Standard mV | 4.0 | 3.0 | 2.0 | 1.0 | 0 |
| Standard mV | 4.0 | 3.0 | 2.1 | 1.1 | 0 |

**c)** Explain the working principle of a linear variable differential transformer (LVDT). Show how it can be used for measuring small mechanical displacements. (5 marks)

**d)** A capacitive type level sensor is to be used for measuring the level of water (conducting) in a tank. With a neat labeled diagram, describe the construction of this sensor. Also state the reason for change in capacitance with change in level of water. (6 marks)

**QUESTION THREE (20 Marks)**

**a)** Define the following sensor/Transducer specifications while giving relevant examples

i. Range (2 marks)

ii. Sensitivity (2 marks)

iii. Stability (2 marks)

iv. Repeatability (2 marks)

**b)** A diaphragm pressure gauge employs four strain gauges to monitor the displacement of the diaphragm. A differential pressure applied to the diaphragm results in two of the gauges on one side of the diaphragm being subject to a tensile strain of 1.0 x 10"^ and the two on the other side a compressive strain of 1.0 x 10"^ The gauges have a gauge factor of 2.1 and resistance 120 Q and are connected in the bridge with the gauges giving subject to the tensile strains in arms 1 and 3 and those subject to compressive strain in arms 2 and 4 (Figure 2.61). If tlie supply voltage for the bridge is 10 V, Calculate the voltage output from the bridge. (6 marks)

**c)** Plot a graph of the following readings for a temperature sensor to determine the linearity of the sensor. What is the nonlinearity as a percentage of FSD? (5 marks)

| True pressure (kPa) | 0 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|
| Gauge reading (kPa) | 0 | 16 | 34 | 56 | 82 | 110 |

**QUESTION FOUR (20 Marks)**

a) What are the errors that occur during the measurement using a thermocouple?(3 marks)

b) What are the secondary transducers used for pressure measurement? Explain anyone them briefly. (4 marks)

c) Why do thermocouples need protection from some operating environments and how is this protection given? Discuss any differences between base metal and noble metal thermocouples in the need for protection. (6 marks)

d) The temperature of a fluid is measured by immersing a type K thermocouple in it. The reference junction of the thermocouple is maintained at $0^0$ C in an ice bath and an output e.m.f. of 6.435 mV is measured. What is the indicated fluid temperature? (4 marks)

The general form of thermocouple relationship is

$$e = a_1T + a_2T^2 + \cdots + a_nT^n$$

where $e$ is the e.m.f. generated and T is the absolute temperature.

**d)** What are piezoresistive sensors and what are they typically used for (3 marks

**QUESTION FIVE (20 Marks)**

**a)** Suggest appropriate types of sensors that would be required for the following applications and briefly show how they can be done

i. To detect non-conducting metallic objects (3 marks)

ii. Thermal energy in solar cells (3 marks)

iii. Level of sulphuric acid in a storage tank. (3 marks)

*The sensor must give an electric signal as output.*

**b)** Compare RTD and thermistor on the basis of Temperature coefficient, Linearity, Temperature range and cost. (6 marks)

**c)** List two applications of potentiometer sensor in/around your home or in the university.

**d)** Describe the procedure to measure pressure using diaphragm with strain gauge. (5 marks)