# University of Ruhuna- Faculty of Technology
**Bachelor of Engineering Technology Honours**
Level 2 (Semester II) Examination, November/December 2023
Academic year 2021/2022

**Course Unit: ENT2232 Instrumentation & Calibration (Theory)**     **Duration: 2 hours**

- This paper consists of **four (4)** questions in **four (4) pages**.
- Answer all **four (4)** questions.
- Use a separate book for answering the questions.
- Each question should be started with a new page.
- Non-programable calculators are allowed.

1)

A) In a local greenhouse, a team of instrumentation engineers has been tasked with designing a comprehensive measuring system to monitor and control environmental conditions and variables for optimal plant growth. The success of the greenhouse operation depends on maintaining the ideal growing conditions.

 i. Define the term "variable". (2 marks)
 ii. Identify **four (04)** physical variables the team should monitor and control in the greenhouse to ensure optimal plant growth. (8 marks)
 iii. Suggest **four (04)** suitable sensors/instruments that can be used to measure and monitor each of the variables identified above. (8 marks)
 iv. Draw a labeled block diagram indicating the **three (03)** main functional elements of your measuring system. (6 marks)
 v. After implementing this system, it is essential to follow periodic calibrations. Explain why such periodic calibrations are essential, giving at least **three (03)** reasons.

(12 marks)

B)
 i. Briefly describe the functions of an instrument/measuring system, giving **one (01)** example for each. (8 marks)
 ii. State **two (02)** applications of instruments/measuring systems. (6 marks)

2)

A) The **sensitivity** of a measuring instrument influences the instrument's ability to detect and respond to even the smallest changes in the quantity being measured.

 i. Briefly explain what is meant by the **sensitivity** of a measuring instrument.

(3 marks)

 ii. An elastic type of pressure measuring instrument is of diaphragm type. The central deflection of the diaphragm was found to be 0.25 mm for an applied pressure of $10^6$ Pa. The output displacement of the diaphragm has been fed to an LVDT (linear variable differential transducer) with a built-in amplifier having a sensitivity ($K_S$) of 40 V/mm.

Finally, the output is displayed on an analog voltmeter which has a radius of scale line of 60 mm and has a voltage range from 0 to 20 volts in an arc of $150^0$. (1 bar $= 10^5$ Pa).

a) State the function of an LVDT. (3 marks)

b) Draw a complete labeled block diagram for this instrument, indicating all the functional elements and variables. (10 marks)

c) Write a mathematical expression for overall sensitivity (K) in terms of transducer sensitivity $K_T$, signal conditioning element sensitivity $K_S$, and the data presentation element sensitivity $K_D$. (3 marks)

d) Determine values of both $K_T$ and $K_D$ separately. Hence calculate the overall sensitivity (K) of the diaphragm gauge in mm/bar. (Hint: Unit of $K_D$ is mm/V) (11 marks)

B) A load cell calibrated at a temperature of 20 $^0$C has the following output/input characteristics.

| Load (kN) | 0 | 0.4 | 0.8 | 1.2 | 1.6 |
|---|---|---|---|---|---|
| Deflection (mm) | 0 | 10 | 20 | 30 | 40 |

When it is used in an environment of 40 $^0$C, its characteristics changes as follows.

| Load (kN) | 0 | 0.4 | 0.8 | 1.2 | 1.6 |
|---|---|---|---|---|---|
| Deflection (mm) | 3 | 14 | 25 | 36 | 47 |

i. Determine the following.
   a) Zero drift.
   b) Static Sensitivity drift.
   c) Sensitivity drift per $^0$C change at 20 $^0$C.

(12 marks)

ii. Sketch a sensitivity characteristic curve for the above load cell indicating the **nominal characteristic curve at 20 $^0$C** and the **zero drift together with the sensitivity drift curve at 40 $^0$C, in the same graph**. Mark the zero-drift value you found in part i.(a) above. Label all the components. (8 marks)

3)

A)

i. Derive dimensions of the following.

   a) $\eta$ ; $F = 6\pi\eta vr$ where F - Force, v – Velocity, r – Radius (2 marks)

   b) $\alpha$ and $\beta$; $T = 2\pi\sqrt{\dfrac{\beta}{g-\alpha}}$ where T – periodic time, g – gravitational acceleration

(3 marks)

ii. The expected value of a voltage to be measured is 150 V. However, the measurement gives a value of 149 V. Calculate,
   a) Absolute error.

b) Percentage error.

c) Relative accuracy.

d) Percentage accuracy.  (2 x 4 marks)

iii. The length and width of a rectangular object are $x$ and $y$ respectively.

a) Derive an expression for the uncertainty in area of the object ($\sigma_A$).  (6 marks)

b) If $x$ and $y$ were measured using a metallic tape which has 0.25 cm error per 30.0 cm of measurement, determine the errors associated with $x$ and $y$. Given that $x = 82.397$ cm and $y = 66.132$ cm.  (4 marks)

c) Calculate the area and its associated uncertainty ($\sigma_A$).  (5 marks)

iv. Briefly explain the following 'terms' using suitable graphical sketches.

a) Non – Linearity

b) Hysteresis  (2x3 marks)

B) Figure (1) shows a mechanical type of pressure-measuring dial gauge. Analyze this figure and briefly explain its working principal. Draw a complete labelled block diagram representing all the functional elements.
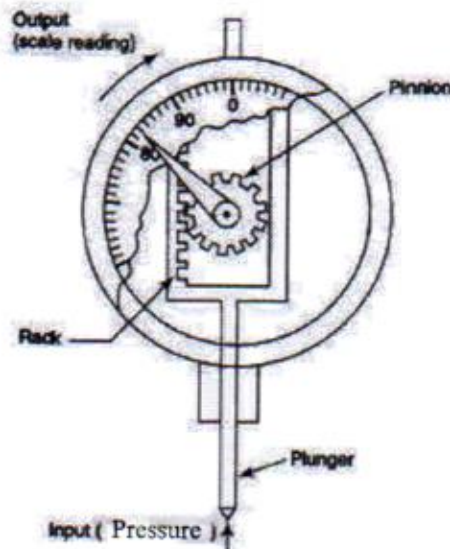


Figure (1)

(16 marks)

4)

A)

i. Define null type and deflection type of instruments.  (4 marks)

ii. Compare and contrast null type and deflection type of pressure measuring instruments in relation to accuracy, usage, and calibration.  (9 marks)

iii. Assume, a resistive type of humidity sensor is required for a project. State **three (03)** factors that you should consider when purchasing this sensor.

(9 marks)

B) The calibration process of an instrument involves comparing the instrument's readings against traceable reference standards with known accuracies. It is important to conduct periodic calibrations in order to maintain the proper performance characteristics of the instrument.

i. Briefly describe the term "periodic calibration". (2 marks)

ii. State **four (04)** reasons for changes in performance characteristics of an instrument.
(8 marks)

iii. Briefly explain what is meant by a "working standard". Give **one (01)** example for your answer. (4 marks)

iv. State **two (02)** established institutions in Sri Lanka responsible for issuing National Measurement Standards. (2 marks)

v. Briefly discuss the importance of **traceability** in a measurement. (12 marks)