B.E. Mechanical Engineering Third Year 2nd Semester Examination – 2025
(3nd Year 2nd Semester)

Subject: **Measurement and Instrumentation**

Time: Three hours **Full Marks: 100**

*Answer any **FIVE** questions. Different parts of the same question should be answered together. Assume any relevant data if necessary. Use of Gaussian Error Function Tables permitted.*

1.	(a)	Draw a schematic of a spring-loaded Bourdon pressure gauge and explain how pressure is converted into pointer deflection. Based on your explanation, identify and illustrate the key functional elements of this measurement system using a block diagram.	12
	(b)	Differentiate between active and passive transducers with suitable examples.	8
2.	(a)	What are systematic and random errors in measurement?	5
	(b)	Why are null-type instruments preferred over deflection-type instruments for high-precision measurements? Also, identify the situations or applications where the use of null-type instruments is not suitable and should be avoided.	5
	(c)	A sports manufacturer produces 5000 cricket bats, where the maximum blade thickness follows a Gaussian distribution with a mean of 65 mm and a standard deviation of 2 mm. As per BCCI regulations, the maximum allowable blade thickness is 67 mm. How many bats are likely to be rejected for exceeding the permitted thickness? (Use of the error function (erf) table is allowed.)	10
3.	(a)	A voltage of 10 V is applied across a 20 kΩ resistor in a circuit. Two voltmeters are available for measurement: Voltmeter A with an internal resistance of 200 kΩ and Voltmeter B with an internal resistance of 20 kΩ (i) Calculate the voltage reading obtained when each voltmeter is connected across the resistor. (ii) Determine the percentage error introduced by each voltmeter due to the loading effect	6 + 4 =10
	(b)	Explain how the direction and magnitude of displacement are determined from the output signal of an LVDT.	6
	(c)	What are primary, secondary, and working standards in calibration?	4
4.	(a)	Define accuracy and precision of an instrument.	4
	(b)	Define input impedance and static stiffness of an instrument. Which type of value (high or low) is desirable for each, and why?	6
	(c)	A strain gauge with a gauge factor of 2.1 is bonded to a structural component. If the unstrained resistance of the gauge is 120 Ω and the measured resistance after loading is 120.252 Ω, calculate the mechanical strain experienced by the component.	10

5. (a) Describe any three commonly used methods for minimizing or correcting the effects of interfering and modifying inputs. Support your explanation with relevant examples. 8

(b) The viscosity of castor oil is determined by "falling sphere method" using the following expression of viscosity

$$\mu=\frac{2r^2}{9U}(\rho_s-\rho_l)g$$

where $r = 1.58 \times 10^{-3}$ m $\pm 3.2 \times 10^{-5}$ m; $U = 76.92 \times 10^{-3}$ m/s $\pm 1.7 \times 10^{-4}$ m/s; ρ_l =953.4 kg/m^3 $\pm$ 0.097 kg/m^3; ρ_s =7850 kg/m^3 $\pm$ 1.297 kg/m^3; $g = 9.81$ m/s^2 $\pm$ 0.03 m/s^2; 8+4 = 12

(a) Evaluate the nominal value of the viscosity and its overall uncertainty.

(b) Identify the critical component in the measurement system that may require more accurate measurement in order to improve the overall uncertainty.

6. (a) With reference to dynamic characteristics of a measurement system, explain the terms – order of the system and transfer function. 5

(b) What will be (i) undamped natural frequency, (ii) damping ratio, (iii) damped natural frequency, (iv) maximum percentage overshoot and (v) 2% settling time for a measurement system whose system transfer function is expressed as: $361/(s^2+16s+361)$. 15

7. (a) A Bourdon pressure gauge having a linear calibration has a 50 mm long pointer. It moves over a circular dial having an arc of 270°. It displays a pressure range of 0 to 15 bar (1 bar = 105 Pa). Determine the sensitivity of the Bourdon gauge in terms of scale length per bar (i.e., mm/bar). 7

(b) A linear time-invariant first-order system is governed by the differential equation: 5

$$m\frac{dq_o(t)}{dt}+n\,q_o(t)=p\,q_i(t)$$

where:
$q_o(t)$ is the system output, $q_i(t)$ is the input, m,n,p are positive constants.

(a) Determine the time constant (τ) of the system

(b) Find the steady-state gain (sensitivity) of the system for a unit step input.

(c) Describe the working principle of a hot wire anemometer. Explain its construction and operation with a neat labeled diagram. 8

8. Write short notes on any FOUR of the following: (a) Time constat of first of order system; (b) Flow and effort variables; (c) Resistance Temperature Detector; (d) Hysteresis and threshold; (e) Primary and secondary standards. 4x5 =20