**GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY**

Faculty of Engineering

Department of Electrical, Electronic and Telecommunication Engineering

B.Sc. Engineering Honours Degree

Semester 8 Examination – Nov/ Dec 2025

(Intake 39 – EE, ET)

# ET 4253 – MECHATRONICS

Time allowed: 3 Hours 10th December 2025

## ADDITIONAL MATERIAL PROVIDED

None

## INSTRUCTIONS TO CANDIDATES

This paper contains 4 questions on pages 3 to 6.

Answer ALL questions

This is a closed book examination

This examination accounts for 60% of the module assessment The marks assigned for each question and parts thereof are indicated in square brackets

If you have any doubt as to the interpretation of the wordings of a question, make your own decision, but clearly state it on the script

Assume reasonable values for any data not given in or provided with the question paper, clearly state such assumptions made in the script

All examinations are conducted under the rules and regulations of the KDU

## DETAILS OF ASSESSMENT

| Learning Outcome (LO) | Questions that assess LO | Marks allocated (Total 60%) |
|---|---|---|
| LO1 | Q1 | 5 |
| LO2 | Q1, Q2 | 15 |
| LO3 | Q1, Q3 | 15 |
| LO4 | Q1, Q4 | 15 |
| LO5 | Q1 | 10 |
| LO6 | - | |

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## Question 1

**[Total 15 marks]**

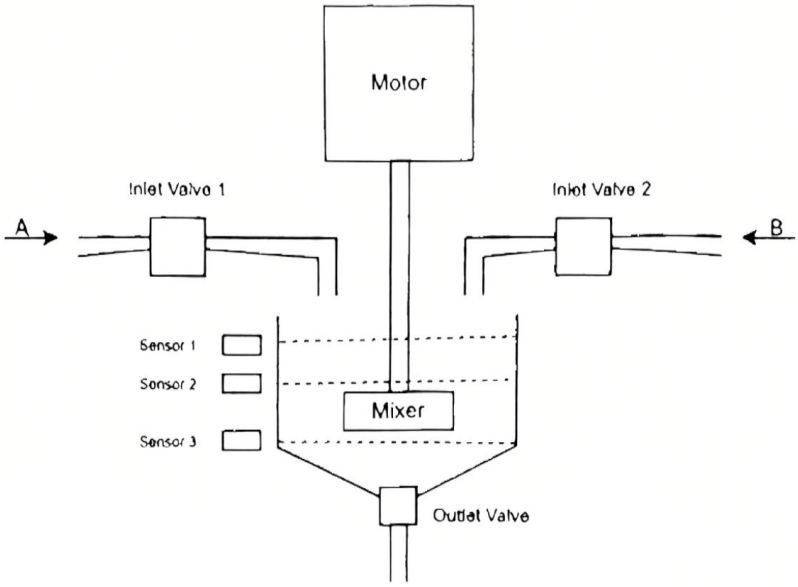



*Figure Q 1.1*

(a) Explain how mechatronics has evolved with the development of Industry 4.0 technologies. [02]

(b) Explain the key components of a mechatronic system and their respective roles. Discuss with the aid of a block diagram. [02]

(c) You are assigned to develop a mobile inspection robot that can navigate inside sewer pipelines to detect cracks and blockages.

i. Explain the design consideration for this task. [04]

ii. Propose two suitable sensors and two actuators for this task. For each component, justify your selection, detailing the functionality of each. [02]

iii. Explain the process of developing a controller for this task. [02]

(d) Figure Q 1.1 represents an automatic controlled mixing tank. In an industrial process, two materials, A and B, are collected in a tank. The collected materials should be mixed for 30 seconds, then released until it reaches the bottom level of the tank. This process has to repeat automatically.

- Two push buttons (Start and Stop) are provided to control the automatic process.
- Three sensors are placed to detect the levels of material A, material B, and the bottom level of the tank.
- Two inlet valves are used to control the flow of material A and B, and an outlet valve is used to release/drain the mixed material.

Write the PLC ladder program that facilitates the automatic mixing of these materials. Clearly indicate each step of the program and use appropriate symbols and notations. Provide comments where necessary to explain the functionality of specific ladder networks. [08]

**Question 2** **[Total 15 marks]**

Table Q2.1 presents a sample data sheet of a temperature sensing module. Refer to the given specifications when answering the following questions.

*Table Q 2.1*

| Parameter | Value |
|---|---|
| Reference Resistance at 0 °C | 100 Ω |
| Temperature Range | −50 °C to +250 °C |
| Sensitivity | 0.385 Ω/°C |
| Accuracy | ±1.0 % full-scale |
| Hysteresis Error | ±0.15 % of measured value |
| Non-linearity Error | ±0.5 % full-scale |
| Time Constant | 0.8 s (first-order response) |
| Current | 18 mA |
| Analog Output (after conditioning) | 0 4.5 V |

(a) Differentiate static and dynamic characteristics of sensors when selecting sensors for mechatronic systems. [02]

(b) Discuss how accuracy, hysteresis, and non-linearity influence the quality of temperature measurements in real-world industrial environments. [03]

(c) Assuming linear behaviour within the temperature range, calculate the resistance of the temperature sensor at 110 °C and determine the corresponding analog voltage. [02]

(d) Determine whether the 10-bit ADC of a microcontroller (with 5V reference) can provide sufficiently precise temperature readings. Explain your reasoning and suggest a practical method to achieve higher measurement accuracy. [02]

(e) In an automated packaging line, pharmaceutical bottles move along a conveyor and must be sorted based on their height and surface texture before labeling and sealing. A sensor-based inspection system is to be designed for this task.

i. What are appropriate sensors that can accurately measure both the height and texture of the bottles during motion on the conveyor. [02]

ii. Explain how these sensors will provide the required precision for high-speed sorting. [02]

(f) What are the challenges and considerations in integrating sensors into Internet of Things (IoT) systems? [02]

**Question 3** **[Total 15 marks]**

A robotic packaging arm is being developed for an automated assembly line. The arm is required to perform precise pick-and-place operations at variable speeds while handling products of different weights. The system must achieve accurate positioning, high repeatability, and quick response in continuous operation.

(a) Discuss how torque, speed and precision influence the suitability of an actuator for this application. [02]

(b) Compare the operating principles and characteristics of DC motors, servo motors and stepper motors, and identify which type is most suitable for use in the robotic packaging arm. Justify your answer with reference to performance and control requirements. [04]

(c) The robotic arm operates in a factory environment where temperature and dust levels fluctuate significantly. Discuss how environmental conditions can affect actuator performance and state design strategies that can improve long-term reliability. [02]

(d) Compare different power sources for actuators, including electric, hydraulic, and pneumatic systems. State the advantages and disadvantages of each power source. [03]

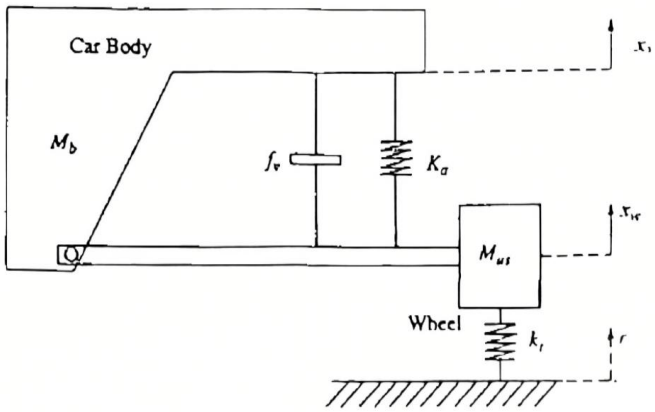
(e) For each of the following scenarios, choose the most suitable actuator and justify your choice.

i. An automated assembly line needs an actuator for precise and reliable positioning of parts in a controlled environment. [02]

ii. A drone requires an actuator to drive propellers with precise control for stable flight and responsive adjustments in varying conditions. [02]

iii. A CNC milling machine needs an actuator for precise rotation and positioning of the cutting tool under varying load conditions. [02]

**Question 4** **[Total 15 marks]**




$M_b$ = car's body mass
$M_{us}$ = wheel's mass
$K_a$ = strut's spring constant
$K_t$ = tire's spring constant
$f_v$ = strut's damping constant
$r$ = road disturbance (input)
$x_s$ = car's vertical displacement
$x_w$ = wheel's vertical displacement

*Figure Q 4.1*

(a) Explain the concept of transfer functions in mechatronic system modeling and how transfer functions are used to analyze the dynamic behavior of a system. [03 marks]

(b) Illustrate the analogy between mechanical and electrical systems by drawing parallels between an RCL (resistor, capacitor, inductor) circuit and a Mass-Spring-Damper system. [04 marks]

(c) Figure Q4.1 shows a quarter car model commonly used for analyzing suspension systems. The tire is assumed to behave as a spring without damping, while the suspension system consists of both a spring and a damper.

i. Derived equations of motion and express the system in terms of Laplace transforms, assuming zero initial conditions. [04 marks]

ii. Derive the transfer function of the system from the road disturbance input R(s) to the car's vertical displacement $X_s(s)$. [04 marks]

End of question paper