25UMET402	MECHATRONICS & INDUSTRIAL AUTOMATION	Category	L	T	P	R	Credit	Year of Introduction
		PCC	3	1	0	0	4	2025

Preamble: Mechatronics and Industrial Automation is an interdisciplinary course designed to provide a comprehensive understanding of the synergistic integration of Mechanical Engineering with Electronics, Control Systems, and Computer Science. The course explores the design and development of "intelligent" systems, moving from basic sensor-actuator frameworks to complex industrial automation involving PLCs, Robotics, and Industry 4.0 standards.

Prerequisite: Nil

Course Outcomes: After the completion of the course, the student will be able to:

CO	Course Outcomes	Knowledge Level
CO1	Describe the working principles of sensing technologies, signal conditioning circuits, and transducers used in mechatronic systems.	K2 Understand
CO2	Describe the working principles of actuators, fluid power components, and precision mechanical elements.	K2 Understand
CO3	Apply mathematical modeling and PID control techniques to analyze mechatronic system behavior.	K3 Apply
CO4	Develop PLC ladder logic programs and demonstrate the use of communication protocols, machine vision, and robotics in industrial automation	K4 Analyze

Mapping of course outcomes with program outcomes and program specific outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO1	2	1	-			-	-	-	-	-	1	2	1
CO2	2	1	-			-	-	-	-	-	1	1	3
CO3	3	3	2	1	2	-	-	-	-	-	1	3	2
CO4	3	3	3	1	3	-	-	-	-	-	1	2	1
Avg	2.5	2	2.5	1	2.5	-	-	-	-	-	1	2	1.75

Mapping of course outcomes with Knowledge and Attitude Profile (WK)

	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
CO1			*	*					
CO2			*	*					
CO3		*	*	*	*				
CO4		*		*	*	*			

WKs Mapped with the course

WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
	*	*	*	*	*			

Mark Distribution:

Total Marks	CIE Marks	ESE Marks	ESE Duration
100	**40**	**60**	**2.5 hrs**

Continuous Internal Evaluation Pattern:

Attendance : 5 marks
Continuous Assessment Test : 20 marks
Continuous Assessment Assignment : 15 marks

SYLLABUS

Module 1 (12 hrs)

Introduction: Definition and structure of Mechatronics systems; Integrated design philosophy; Comparison between traditional and mechatronic systems.
Sensing Technologies: Environmental: Temperature (RTD, Thermocouple), Flow, and Pressure sensors. Proximity & Displacement: Magnetic, optical, ultrasonic, inductive, capacitive, and eddy current methods. Motion Feedback: Incremental and absolute encoders (Gray coding); Resolvers.
Advanced Dynamics: Piezoelectric sensors; Vibration sensors (Principles and selection).
Signal Conditioning: Operational Amplifiers (Inverting, Non-inverting, Summing); Filtering; Analog-to-Digital (ADC) and Digital-to-Analog (DAC) conversion fundamentals.

Module 2 (14 hrs)

Electrical Actuators: Principles and selection of DC, AC, Brushless DC (BLDC), Servo, and Stepper motors; Electronic Speed Controllers (ESC).
Fluid Power Systems: Components: Hydraulic and Pneumatic actuators; Directional, pressure, and process control valves. Circuit Design: Development of hydraulic and pneumatic circuits using standard ISO symbols; Introduction to Proportional Control.
Precision Mechanical Elements: Harmonic drives; Anti-friction/hydrostatic bearings; Pre-loaded re-

circulating ball and roller screws.

Module 3 (15 hrs)

Mathematical Modeling: Building blocks for mechanical, electrical, fluid, and thermal systems; Introduction to transfer functions.

Control Theory: Open and closed-loop systems; Typical elements; Feedback control and introduction to PID tuning.

MEMS (Micro-Electro-Mechanical Systems): Working principles and applications of MEMS-based pressure sensors, accelerometers, and gyroscopes (Micromachining overview).

CNC Mechatronics: Design of modern CNC machines; Direct and indirect measuring systems; Adaptive control and real-time optimization for machine tools.

Module 4 (15 hrs)

Programmable Logic Controllers (PLC): Basic structure and I/O processing; Programming: Timers, Internal Relays, Counters, and Shift registers; Ladder logic programs for industrial sequences.

Interfacing & Networking: Introduction to Signal Conditioning; Communication Protocols (IO-Link, EtherCAT).

Robotics & Machine Vision: Force and tactile sensors; Machine Vision acquisition (CCD/CMOS); Image Processing: Thresholding and edge detection for part recognition.

Case Studies: Automatic car park barriers; Pick-and-place robots; Automobile Engine Management Systems (EMS).

Industry 4.0: Brief overview of Digital Twins, IIoT integration, and Edge Computing in automation.

Text Books:

1. Bolton, W. *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, 6th ed., Pearson Education, 2015.
2. Shetty, D., and Kolk, R. A. *Mechatronics System Design*, 2nd ed., Cengage Learning, 2011.
3. Alciatore, D. G., and Histand, M. B. *Introduction to Mechatronics and Measurement Systems*, 5th ed., Tata McGraw Hill, 2018.

Reference Books

1. Onwubolu, G. C. *Mechatronics: Principles and Applications*, Butterworth-Heinemann, 2005.
2. Majumdar, S. R. *Oil Hydraulics Systems: Principles and Maintenance*, Tata McGraw Hill, 2001.
3. Petruzella, F. D. *Programmable Logic Controllers*, 5th ed., McGraw Hill Higher Education, 2016.
4. Mahalik, N. P. *Mechatronics: Principles, Concepts and Applications*, Tata McGraw Hill, 2003.

END SEMESTER EXAMINATION – MODEL QUESTION PAPER

Course Code	**25UMET402**
Course Name	**MECHATRONICS & INDUSTRIAL AUTOMATION**
Max. Marks: 60	**Duration: 2.5 Hours**

Part A *(Answer all questions. Each question carries 3 marks)*				
Qn No.	**Question**	**Marks**	**CO**	**BL**

1	Define a Mechatronics system and explain its integrated design philosophy with a comparison between traditional and mechatronic systems.	3	CO 1	L2
2	Differentiate between incremental and absolute encoders used in motion feedback systems.	3	CO 1	L2
3	Apply the principles of signal conditioning to explain the role of an operational amplifier in sensor circuits.	3	CO 2	L3
4	Relate the working principle of a stepper motor to its use in precision positioning applications.	3	CO 2	L3
5	Explain the construction and working of a hydraulic actuator with the help of a circuit diagram.	3	CO 3	L2
6	Describe the mathematical modeling approach for a fluid system and derive its transfer function.	3	CO 3	L2
7	Interpret the role of PLC ladder logic programming in controlling an industrial sequence.	3	CO 4	L3
8	Explain the working principle of Machine Vision and its application in part recognition using edge detection.	3	CO 4	L3
Part B (*Answer any one full question from each Module. Each carry 9 marks*)				
Module I				
Qn No.	**Question**	**Marks**	**CO**	**BL**
9	Explain the working principle of an incremental encoder with Gray coding and describe the signal conditioning circuit using a non-inverting operational amplifier to process the encoder output.	9	CO1	L2
OR				
10	Describe the working principles of inductive and capacitive proximity sensors and explain their characteristics for detecting metallic and non-metallic objects in industrial applications.	9	CO1	L2
Module II				
Qn No.	**Question**	**Marks**	**CO**	**BL**
11	Describe the working principles of stepper motor and servo motor. Explain the role of an Electronic Speed Controller (ESC) in motor drive systems and state the selection criteria for each motor type.	9	CO2	L2
OR				

12	Explain the components of a hydraulic circuit for a double-acting cylinder including the 4/3 directional control valve, pressure relief valve, and flow control valve. Describe the function of each component using standard ISO symbols.	9	CO2	L2
Module III				
Qn No.	**Question**	**Marks**	**CO**	**BL**
13	A closed-loop temperature control system uses a thermocouple as sensor and a heater as actuator. Derive the transfer function of the system and apply PID tuning to improve its transient response.	9	CO3	L3
OR				
14	Apply the concepts of direct and indirect measuring systems to a modern CNC milling machine. Explain adaptive control and real-time optimization strategies used for improving machining accuracy and tool life.	9	CO3	L3
Module IV				
Qn No.	**Question**	**Marks**	**CO**	**BL**
15	Develop a PLC ladder logic program for an automatic car park barrier system. The barrier should open when a valid token is detected and close after a 10-second timer. Include timers, counters, and internal relays in the program.	9	CO4	L4
OR				
16	Demonstrate how machine vision is applied in a pick-and-place robot for part recognition. Explain the image acquisition process and apply thresholding and edge detection techniques to identify and locate a component on a conveyor.	9	CO4	L4