R25-M.Tech (Robotics and Automation)
PG Course Structure and Syllabus

I-SEMESTER

S. No.	Course Code	Course Title	Contact hours/week			Credits	Scheme of Valuation		
			L	T	P		CIE	SEE	Total
Theory Courses									
1	D251BD01	Principles of Robotics	3	1	0	4	40	60	100
2	D251BD02	Industrial Automation	3	1	0	4	40	60	100
3	D251BD03	Artificial Intelligence and Machine Learning in Robotics	3	1	0	4	40	60	100
4	PROGRAM ELECTIVE-I		3	0	0	3	40	60	100
5	PROGRAM ELECTIVE-II		3	0	0	3	40	60	100
Laboratory Courses									
6	D251BD90	Robotics and IoT Lab	0	1	2	2	40	60	100
7	D251BD91	Industrial Automation Lab	0	1	2	2	40	60	100
8	D2510080	Seminar-I	0	0	2	1	100	-	100
Total			**15**	**5**	**6**	**23**	**380**	**420**	**800**

List of Professional Elective Courses in I Semester (Electives – I & II)

Course Code	Course Title
D251BDA0	Smart Materials and Intelligent Manufacturing
D251BDA1	Microcontrollers & Applications
D251BDA2	Robot Safety and Maintenance
D251BDA3	Embedded Processor Architecture
D251BDB0	Natural Language Processing for Robots
D251BDB1	Introduction to Quantum Technologies
D251BDB2	Knowledge Engineering and Expert Systems
D251BDB3	Design of Experiments

II-SEMESTER

S. No.	Course Code	Course Title	Contact hours/week			Credits	Scheme of Valuation		
			L	T	P		CIE	SEE	Total
Theory Courses									
1	D252BD01	Robot Motion Analysis and Controls	3	1	0	4	40	60	100
2	D252BD02	Robot Sensors and Actuators	3	1	0	4	40	60	100
3	D252BD03	Electro Mechanical Actuation Systems	3	1	0	4	40	60	100
4	PROGRAM ELECTIVE-III		3	0	0	3	40	60	100
5	PROGRAM ELECTIVE-IV		3	0	0	3	40	60	100
Laboratory Courses									
6	D252BD90	Product Life-cycle Management Lab	0	1	2	2	40	60	100
7	D252BD91	Robotics Simulation Lab	0	1	2	2	40	60	100
8	D2520080	Seminar-II	0	0	2	1	100	-	100
Total			**15**	**5**	**6**	**23**	**380**	**420**	**800**

List of Professional Elective Courses in II Semester (Electives – III & IV)

Course Code	Course Title
D252BDA0	Mobile and Micro Robots
D252BDA1	Machine Vision
D252BDA2	Digital Signal & Image Processing
D252BDA3	Multi Agent Systems
D252BDB0	Reinforcement Learning for Robotics
D252BDB1	Robotics in Industry 4.0
D252BDB2	Embedded System Design
D252BDB3	Advanced Operations Research

III-SEMESTER

S. No.	Course Code	Course Title	Contact hours/week			Credits	Scheme of Valuation		
			L	T	P		CIE	SEE	Total
1	D2530001/M	Research Methodology and IPR / *Swayam 12 week MOOC course– RM&IPR*	3	0	0	3	40	60	100
2	D253000S	Summer Internship /Industrial Training (8-10 weeks)*	-	-	-	3	100	-	100
3	D25300CV	Comprehensive Viva#	-	-	-	2	100	-	100
4	D253000P	Dissertation Part– A$	-	-	20	10	100	-	100
Total			**3**	**0**	**20**	**18**	**340**	**60**	**400**

* Student attended during summer / year break and assessment will be done in 3 rd Sem. # Comprehensive viva can be conducted courses completed upto second sem.

$ Dissertation – Part A, internal assessment.

IV-SEMESTER

S. No.	Course Code	Course Title	Contact hours/week			Credits	Scheme of Valuation		
			L	T	P		CIE	SEE	Total
1	D254000P	Dissertation Part– B%	0	0	32	16	-	100	100
Total			**0**	**0**	**32**	**16**	**-**	**100**	**100**

% External Assessment

Total Credits: 23+23+18+16= 80

Programme Outcomes for P.G Programme

R25 - M.Tech (Robotics and Automation)

PO	PO Statement
PO1	An ability to independently carry out research / investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the programme. The mastery should be at a level higher than the requirements in the appropriate Bachelor programme.
PO4	Model and design Robotic systems applying for Automation Solutions.
PO5	Adopt methods of Technology conservation for sustainable development with robotics.

M.Tech. (I Sem.) **D251BD01- PRINCIPLES OF ROBOTICS**

L	T	P	C
3	1	0	4

PRE-REQUISITES:

Students should have basic knowledge of Engineering Mechanics, Control Systems, electrical and electronics fundamentals, and programming concepts. Familiarity with manufacturing systems and automation will help students understand robotic systems and industrial robotic applications effectively.

COURSE EDUCATIONAL OBJECTIVES (CEOs):

The course is designed to provide students with fundamental knowledge of robotics, including robot anatomy, classification, kinematics, sensors, end effectors, control systems, and programming concepts. The students will develop the ability to analyze robotic configurations, select suitable robotic components, and implement robotic programming techniques for industrial applications. The course also aims to enhance understanding of robotic applications, safety standards, and socio-economic aspects of robotics and automation in modern industries.

COURSE OUTCOMES (COs):

At the end of the course, the student will be able to

CO1: Apply the concepts of robot anatomy, classification, and kinematic configurations to identify suitable robotic systems for engineering applications. **(Applying-L3)**

CO2: Apply the principles, selection criteria, and force analysis of robotic end effectors and grippers used in industrial automation. **(Applying-L3)**

CO3: Analyze robot control systems and sensor integration techniques for precise robotic motion and feedback control. **(Analyzing-L4)**

CO4: Explain robotic programs using suitable robotic programming languages and platforms for robotic control applications. **(Applying-L3)**

CO5: Analyze industrial and service applications of robotic systems and evaluate their socio-economic impact and safety considerations. **(Analyzing-L4)**

UNIT–I: Introduction to Robotics and Robot Anatomy

Robot classification, types and components of robot anatomy, robot terminology-links, joints, DoF, specification of a robot, work volume, work space, work object, robot geometrical configuration (PPP, RPP, RRP, RRR, etc.) control resolution & spatial resolution, of robotics, accuracy and repeatability, dexterity, compliance, RCC device of robotics, robot drive systems-hydraulic, pneumatic and electric system.

UNIT–II: Robot End Effectors and Grippers

Robot end effectors-classification grippers, types of grippers-mechanical, finger grippers, magnetic-vacuum/suction, hooks, scoops, grippers in humanoid robots, selection of grippers, gripping mechanisms, gripper force analysis and design of drive system for gripper, tools characteristics and elements of end-of-arm-tooling.

UNIT–III: Sensors and Robot Control Systems

Feedback devices-encoder, resolver, LVDT-motion interpolations, adaptive control sensors in robot, characteristics of sensing devices, selections and need of sensors, touch sensors-tactile

sensor, proximity and range sensors, force sensor-light sensors, pressure sensors, robotic vision sensor, performance 0f the control system by integrating various sensors in robotic system

UNIT–IV: Robot Programming and Work Cell Design

Robot programming: methods of robot programming, WAIT, SIGNAL and DELAY commands, subroutines, programming languages: generations of robotic languages, introduction to various types such as VAL, RAIL, AML, python, ROS etc., robot work cell design - control-sequence control operator interface, safety monitoring devices in robot.

UNIT–V: Applications of Robotics and Socio-Economic Aspects

Robot applications in Machining – Welding – Assembly – Material handling –Loading and unloading – spray painting, Robot capabilities-wheeled, tracked, legged, aerial, underwater robots, surgical robots, rehabilitation robots, humanoid robots, Nano Robots.

Socio-economic aspect of robotization. Economical aspects for robot design, safety for robot and standards.

Text Books

1. Industrial Robotics: Technology, Programming, and Applications, M. P. Groover, M. Weiss, R. N. Nagel, and N. G. Odrey, *Industrial Robotics: Technology, Programming, and Applications*, McGraw-Hill Publications.
2. Introduction to Robotics: Mechanics and Control, J. J. Craig, *Introduction to Robotics: Mechanics and Control*, 3rd Edition, Pearson Education, 2005.
3. Robotics for Engineers, S. B. Niku, *Robotics for Engineers (Mechanical Perspective)*, Wiley Publications, 2015.

Reference Books

1. Introduction to Robotics, S. K. Saha, *Introduction to Robotics*, 2nd Edition, Tata McGraw-Hill, 2014.
2. Robotics and Control, R. K. Mittal and I. J. Nagrath, *Robotics and Control*, Tata McGraw-Hill Publications.
3. Robot Technology: Fundamentals and Applications, James G. Keramas, *Robot Technology: Fundamentals and Applications*, Cengage Learning.
4. Robot Analysis and Control, H. Asada and J.-J. E. Slotine, *Robot Analysis and Control*, Wiley Publications.

M.Tech. (I Sem.) **D251BD02- INDUSTRIAL AUTOMATION**

L	T	P	C
3	1	0	4

Pre-requisites:

COURSE EDUCATIONAL OBJECTIVES (CEOs): The course aims to enable students to analyze, design, and implement advanced industrial automation systems by integrating modern technologies such as PLC, SCADA, DCS, IoT, and Industry 4.0 concepts for improving productivity, safety, and efficiency in manufacturing and process industries.

Course Outcomes: At the end of the course the student will be able to

CO1: Analyze automation strategies, industrial revolutions, and Industry 4.0 technologies in modern manufacturing systems. **(Analyzing-L4)**

CO2: Analyze IoT, cyber-physical systems, cloud computing, and automated flow lines used in smart manufacturing environments. **(Analyzing-L4)**

CO3: Design and implement PLC-based industrial automation systems using ladder logic, timers, counters, and industrial communication interfaces. **(Evaluating-L5)**

CO4: Evaluate automated manufacturing and material handling systems including AGVs, conveyors, cellular manufacturing, and FMS. **(Analyzing-L4)**

CO5: Develop and integrate SCADA and DCS architectures with industrial safety and cybersecurity considerations for process industries. **(Evaluating-L5)**

UNIT–I: Automation and Industry 4.0 Fundamentals

Introduction to automation in manufacturing and process industries. Principles and strategies of automation. Basic elements of automated systems. Advanced automation functions and levels of automation.

Industrial revolutions and evolution toward Industry 4.0. Digitalization and the networked economy. Drivers, enabling technologies, compelling forces, opportunities, and challenges of Industry 4.0 in smart manufacturing environments.

UNIT–II: Industry 4.0 Enabling Technologies and Smart Manufacturing

Overview of Industry 4.0 enabling technologies – Internet of Things (IoT), cloud computing, cyber-physical systems (CPS), and industrial communication networks.

Automated flow lines and transfer mechanisms – analysis of transfer lines without storage buffers and with storage buffers. Introduction to smart manufacturing – smart devices, smart products, smart logistics, smart factories, predictive analytics, and data-driven manufacturing systems.

UNIT–III: Programmable Logic Controllers and Industrial Automation

Introduction to Programmable Logic Controllers (PLC). History and evolution of PLCs. PLC architecture – CPU, I/O modules, power supply, communication modules, and memory organization. Input and output devices used in industrial automation.

Need and applications of PLCs in industrial automation. Types of PLC models and industrial PLC systems. PLC programming languages – ladder logic diagrams, function block diagrams, structured text, and sequential function charts. PLC instructions – examine ON/OFF, timers, counters, data manipulation, arithmetic functions, and advanced programming instructions with industrial case studies.

UNIT–IV: Material Handling and Automated Manufacturing Systems

Overview of material handling systems. Types of material handling equipment and system design considerations. Conveyor systems and automated guided vehicle (AGV) systems.

Automated manufacturing systems – components, classification, and overview of manufacturing systems. Cellular manufacturing systems, flexible manufacturing systems (FMS), computer-integrated manufacturing (CIM), and automated production planning concepts.

UNIT–V: SCADA and Distributed Control Systems

Introduction to Supervisory Control and Data Acquisition (SCADA) systems – definition, history, architecture, communication requirements, desirable properties, features, advantages, disadvantages, and applications.

SCADA architectures – monolithic, distributed, and networked SCADA systems. Industrial applications and case studies of SCADA systems.

Distributed Control Systems (DCS) – introduction, Local Control Unit (LCU) architecture, process interfacing issues, security approaches, and networking of DCS systems. Real-time data acquisition and analysis, historian systems, integration of business systems with process data, and remote terminal units (RTUs).

Text Book:

1. M.P.Groover, “Automation, Production Systems, and Computer-Integrated Manufacturing, 5th edition, Pearson, 2024

Reference Books:

1. John W. Webb and Ronald A. Reis, “Programmable Logic Controllers: Principles and Applications”, 5th Edition, Prentice Hall Inc., New Jersey, 2003.
2. Krishna Kant, “Computer - Based Industrial Control”, 2nd Edition, Prentice Hall, New Delhi, 2011.
3. Frank D. Petruzella, “Programmable Logic Controllers”, 5th Edition, McGraw- Hill, New York, 2016.

M.Tech. (I Sem.)	D251BD03- ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN ROBOTICS	L	T	P	C
		3	1	0	4

PRE-REQUISITES: Basics of Programming, Engineering Mathematics, Sensors and Control Systems, Fundamentals of Robotics.

COURSE EDUCATIONAL OBJECTIVES (CEOs): The student will acquire knowledge of the fundamentals of Artificial Intelligence, Machine Learning, and Robotics, intelligent robotic systems, autonomous decision-making techniques, machine learning algorithms for robotics, and the design of AI-based robotic solutions for industrial and real-world applications.

COURSE OUTCOMES (COs): At the end of the course, the student will be able to:

CO1: Understand the fundamentals of Artificial Intelligence, Machine Learning, and robotic systems. **(Understanding – L2)**

CO2: Apply machine learning algorithms for robotic applications and intelligent decision-making. **(Applying – L3)**

CO3: Analyze robotic sensing, perception, and navigation techniques using AI concepts. **(Analyzing-L4)**

CO4: Explain AI-enabled robotic systems for automation and industrial applications. **(Applying-L3)**

CO5: Evaluate advanced robotic applications involving deep learning and autonomous systems. **(Evaluating – L5)**

UNIT – I: Introduction to AI and Robotics

Introduction to Artificial Intelligence, History and Applications of AI, Fundamentals of Robotics, Components of Robotic Systems, Robot Configurations and Degrees of Freedom, Sensors and Actuators in Robotics, Robot Kinematics, Intelligent Robots, Applications of AI in Robotics.

UNIT – II: Machine Learning Fundamentals

Introduction to Machine Learning, Types of Machine Learning, Supervised Learning, Unsupervised Learning, Reinforcement Learning, Data Collection and Preprocessing, Regression Algorithms, Classification Algorithms, Clustering Techniques, Model Evaluation Methods, ML Tools and Frameworks.

UNIT – III: AI Techniques for Robotics

Knowledge Representation, Search Algorithms, Expert Systems, Fuzzy Logic, Artificial Neural Networks, Computer Vision Basics, Image Processing for Robotics, Pattern Recognition, Robotic Perception, Object Detection and Recognition, Decision-Making in Robots.

UNIT – IV: Autonomous Robots and Deep Learning

Autonomous Mobile Robots, Localization and Mapping, Path Planning Algorithms, Obstacle Detection and Avoidance, Deep Learning Fundamentals, Convolutional Neural Networks (CNN), Deep Learning in Robotic Vision, Human–Robot Interaction, Swarm Robotics, Industrial Robotic Automation.

UNIT – V: Advanced Applications of AI and ML in Robotics

Collaborative Robots (Cobots), AI in Industrial Automation, Predictive Maintenance using ML, Robotic Process Automation (RPA), IoT and Cloud Robotics, Smart Manufacturing and Industry 4.0, Autonomous Vehicles and Drones, Medical and Service Robots, Ethical and Safety Issues in AI Robotics, Case Studies and Mini Project.

TEXT BOOKS

1. M. P. Groover, *Industrial Robotics: Technology, Programming and Applications*, McGraw Hill.
2. S. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*, Pearson Education.
3. Ethem Alpaydin, *Introduction to Machine Learning*, MIT Press.

REFERENCE BOOKS

1. Kevin P. Murphy, *Machine Learning: A Probabilistic Perspective*, MIT Press.
2. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, MIT Press.
3. Saeed B. Niku, *Introduction to Robotics: Analysis, Control and Applications*, Wiley.
4. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, MIT Press.

ONLINE RESOURCES

1. NPTEL Courses on Artificial Intelligence and Robotics
2. TensorFlow Official Documentation
3. PyTorch Documentation
4. ROS Documentation

M.Tech. (I Sem.) **D251BD90- ROBOTICS AND IOT LAB**

L	T	P	C
0	1	2	2

Prerequisites

Students should have basic knowledge of Robotics, Embedded Systems, programming fundamentals, sensors and actuators, control systems, and fundamentals of electronics and communication required for interfacing and automation applications.

Course Educational Objectives

The course is designed to provide practical exposure to robotic systems, embedded platforms, and IoT-based automation technologies through hands-on laboratory experiments. The students will develop the ability to program and simulate robotic operations, interface sensors and actuators with Arduino/Raspberry Pi platforms, implement real-time monitoring and control strategies, and analyze robotic system performance using data acquisition and control techniques. The course also aims to enhance the students' skills in designing intelligent IoT-enabled robotic applications for industrial automation, smart monitoring, and autonomous systems.

Course Outcomes: At the end of the course, the student will be able to:

CO1: Apply robotic system configuration, programming, and simulation techniques for performing industrial robotic operations such as writing, pick-and-place, and shape identification. **(Applying-L3)**

CO2: Develop embedded system applications using Arduino/Raspberry Pi by interfacing various sensors, actuators, and control devices for robotic and automation applications. **(Applying-L3)**

CO3: Analyze the performance of robotic and embedded control systems using PID controllers, DAQ systems, ADC/DAC interfacing, and multi-process operations. **(Analyzing-L4)**

CO4: Evaluate robotic motion control, sensor integration, and real-time monitoring techniques for autonomous and intelligent robotic applications. **(Evaluating-L5)**

CO5: Design and implement IoT-enabled robotic and automation systems using open platforms for real-time industrial and smart monitoring applications. **(Evaluating-L5)**

LIST OF EXERCISES

Any twelve exercises from the following to be performed

1. Configuration and calibration of robotic systems and robotic workspaces.
2. Robot programming and simulation for writing practice.
3. Robot programming and simulation for pick-and-place operations.
4. Robot programming and simulation for shape identification and sorting applications.
5. Study of forward and inverse kinematics of robotic manipulators using simulation tools.
6. Trajectory planning and motion control of robotic manipulators.
7. Robot path planning and obstacle avoidance using simulation software.
8. Interfacing and control of mobile robot/wheeled robot using Arduino/Raspberry Pi.
9. Interfacing of ultrasonic sensor for robotic distance measurement and obstacle detection.
10. Line follower robot design and implementation using IR sensors and microcontroller.
11. Wireless control of robotic systems using Bluetooth/Wi-Fi modules.
12. Basics of Arduino/Raspberry Pi programming, installation of Arduino IDE, and interfacing with computer systems.
13. Interfacing of temperature and humidity sensor (DHT11) with Arduino/Raspberry Pi.
14. Interfacing and control of high-voltage buck converter devices using Arduino/Raspberry Pi.
15. Interfacing of LDR sensor, relay, and bulb using Arduino/Raspberry Pi for automated lighting applications.

16. Servo motor interfacing and position control using Arduino/Raspberry Pi.
17. Design and performance evaluation of PID controller using Arduino/Raspberry Pi.
18. Design and development of IoT-based smart applications using Arduino/Raspberry Pi/open-source

Reference Books

1. Programming Arduino: Getting Started with Sketches, Simon Monk, *Programming Arduino: Getting Started with Sketches*, 2nd Edition, McGraw-Hill Education, 2016.
2. Exploring Raspberry Pi, Derek Molloy, *Exploring Raspberry Pi: Interfacing to the Real World with Embedded Linux*, Wiley Publications, 2016.
3. Industrial Robotics, Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, and Nicholas G. Odrey, *Industrial Robotics: Technology, Programming and Applications*, McGraw-Hill Education, 2012.
4. Robot Modeling and Control, Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, Wiley India, 2020.
5. Internet of Things: A Hands-On Approach, Arshdeep Bahga and Vijay Madisetti, *Internet of Things: A Hands-On Approach*, Universities Press, 2015.

References: Lab Manual

M.Tech. (I Sem.) **D251BD91- INDUSTRIAL AUTOMATION LAB**

L	T	P	C
0	1	2	2

Prerequisite: Sensors & Actuators, Control Systems, Basics of PLC

Students should have basic knowledge of Industrial Automation, sensors and actuators, control systems, electrical circuits, and fundamentals of PLC programming. Familiarity with industrial instrumentation and basic programming concepts will help students understand automation system integration and industrial process control effectively.

Course Educational Objective: This lab provides hands-on exposure to industrial automation systems including PLC programming, sensors, actuators, industrial communication, SCADA basics, and integration with robotic systems. Students design and implement automation solutions for real-world industrial processes

.

Course Outcomes: At the end of the course, the student will be able

CO1: Explain the architecture, programming concepts, and operational principles of PLC-based industrial automation systems. **(Understanding – L2)**

CO2: Analyze the working principles and interfacing methods of industrial sensors and actuators used in automation systems. **(Analyzing-L4)**

CO3: Analyze sequential control and industrial process control strategies used in automation applications. **(Analyzing-L4)**

CO4: Apply industrial communication protocols and SCADA systems for monitoring and control of industrial processes. **(Applying-L3)**

CO5: Evaluate the performance, reliability, and troubleshooting methods of industrial automation and control systems. **(Evaluating-L5)**

Lab Experiments

1. PLC hardware familiarization and identification of input/output modules.
2. Basic PLC programming using ladder logic instructions.
3. Implementation of timer and counter applications using PLC.
4. Sequential control operations using PLC programming.
5. Integration of industrial sensors with PLC systems.
6. Actuator interfacing and control using PLC.
7. PLC-based motor control applications.
8. Analog input/output handling and signal conditioning using PLC.
9. Human Machine Interface (HMI) design and implementation.
10. Introduction to SCADA systems and real-time monitoring.
11. Industrial communication using PLC communication protocols.
12. Development of automated sorting systems using sensors and PLC.
13. Pick-and-place automation using PLC and actuators.
14. Fault detection, diagnostics, and troubleshooting of industrial automation systems.

Mini Project / Capstone Task

Develop a complete industrial automation system for applications such as:

- Automated bottling plant
- Smart conveyor sorting system

- Robotic pick-and-place system
- Automated warehouse module
- Process control system (temperature/level control)

Project Requirements

- PLC program development
- Sensor and actuator integration
- HMI/SCADA interface implementation
- System testing, validation, and documentation

List of Equipment / Software

Hardware

- PLC Trainer Kits (Siemens / Allen-Bradley / Delta)
- Sensors: Proximity, IR, photoelectric, and limit switches
- Actuators: Motors, solenoids, and relays
- HMI panels
- Conveyor setup and automation trainer kits

Software

- TIA Portal
- RSLogix
- WPLSoft
- WinCC / Wonderware
- MATLAB / Simulink *(optional integration)*

Recommended Books / References

1. Programmable Logic Controllers, W. Bolton, *Programmable Logic Controllers*, 6th Edition, Newnes Publications, 2015.
2. Programmable Logic Controllers, Frank D. Petruzella, *Programmable Logic Controllers*, 5th Edition, McGraw-Hill Education, 2016.
3. Automation, Production Systems, and Computer-Integrated Manufacturing, Mikell P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, 4th Edition, Pearson Education, 2015.
4. PLC and SCADA software manuals for industrial automation applications.

M.Tech. (I Sem.)	D251BDA0- SMART MATERIALS AND INTELLIGENT MANUFACTURING	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL OBJECTIVES: This course aims to provide knowledge of smart materials, intelligent manufacturing systems, integrated with Industry 4.0, automation, sensors, AI- concepts for advanced industrial applications.

Course Outcomes: At the end of the course the student will be able to

CO1: Apply the concepts of smart structures and applications of piezoelectric devices and shape memory alloys in engineering systems. **(Applying-L3)**

CO2: Analyze the behavior and applications of magnetostrictive materials and ER/MR fluids in smart systems. **(Analyzing-L4)**

CO3: Apply the concepts of Industry 4.0, cyber-physical systems, and digital technologies in intelligent manufacturing systems. **(Applying-L3)**

CO4: Evaluate knowledge-based systems for equipment selection and manufacturing system design applications. **(Evaluating-L5)**

CO5: Analyze AI and ML applications in process control, predictive maintenance, additive manufacturing, and smart factories. **(Analyzing-L4)**

UNIT-I

Smart Structures: Introduction to smart materials, Components of a smart system, Evolution of smart materials and structures. Piezoelectric Actuators (PZT) and Sensors: Fundamentals of Piezoelectricity, Basic Piezoceramic Characteristics and its application. Shape Memory Alloys (SMA): Fundamentals of Shape Memory Alloy (SMA) behaviour and its applications.

UNIT-II

Magnetostrictive: Mechanism of Magnetostriction, Properties of Magnetostrictive materials, Magneto-mechanical Coupling, Magnetostrictive Actuators, Magnetostrictive Sensors. Electrorheological and Magnetorheological Fluids: Fundamental Composition and Behavior of ER/MR Fluids, ER and MR Fluid Dampers and Modeling of ER/MR Fluid Dampers; Applications of Active Materials in Integrated Systems.

UNIT-III

Introduction to Manufacturing systems: Various subsystems in manufacturing systems, procurement, design, manufacturing, inspections, assembly, prototyping, material handling, storage systems. Intelligent Manufacturing Systems: System components, architecture and data flow, operation, Concepts of Industry 4.0 and Smart Factory, Cyber-Physical Systems (CPS), Flexible and reconfigurable manufacturing systems, Digital twins and virtual manufacturing, Human-machine collaboration.

UNIT-IV

Knowledge Based Systems: Knowledge representation, Interference Engine, Knowledge Acquisition; Knowledge based system for equipment selection (KBSES): Manufacturing system

design, modeling the manufacturing equipment selection problem, problem Solving approach in KBSES, Structure of the KBSES.

UNIT-V

AI and Data-Driven Manufacturing: Role of AI and ML in process monitoring and control, Predictive maintenance and quality control, Edge computing and Industrial Internet of Things in manufacturing, Additive Manufacturing with Smart Integration: Basics of 3D printing and metal additive manufacturing, Smart control and real-time feedback, Multi-material and functionally graded materials, Integration of smart sensors and control systems.

Text Books:

1. I. Chopra and J. Sirohi, Smart Structures: Theory, Cambridge, U.K.: Cambridge Univ. Press, 2013. (Unit- I and II)
2. F. Zhang, Intelligent Manufacturing. Hoboken, NJ, USA: Wiley. (Unit- III)
3. A. Kusaic, Intelligent Manufacturing Systems, Englewood Cliffs, NJ, USA: PrenticeHall, 1990. (Unit- IV and V)

Reference Book:

1. M. P. Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, 4th ed. Boston, MA, USA: Pearson, 2016.

M.Tech. (I Sem.)	D251BDA1- MICROCONTROLLERS & APPLICATIONS	3	0	0	3

PREREQUISITES:
Students should have basic knowledge of Computer Fundamentals, digital electronics, C programming, logic design, and fundamentals of embedded systems. Familiarity with electronic components, microprocessor concepts, and interfacing techniques will help students understand microcontroller programming and hardware integration effectively.

COURSE EDUCATIONAL OBJECTIVES (CEOS):
The course is designed to provide students with comprehensive knowledge of AVR microcontrollers, embedded programming, and Arduino-based system development for real-time applications. The students will develop the ability to write assembly and embedded C programs, interface sensors and actuators, configure communication peripherals, and implement control applications using Arduino platforms. The course also aims to enhance practical skills in hardware interfacing, firmware development, and embedded system design for industrial automation, robotics, and IoT applications.

Course Outcomes: At the end of the course the student will be able to
CO1: Apply the concepts and architecture of AVR microcontrollers in embedded system applications. **(Applying-L3)**
CO2: Develop assembly language programs for AVR microcontrollers using addressing modes, I/O operations, and control instructions. **(Applying-L3)**
CO3: Implement embedded C programs for AVR microcontrollers involving timers, counters, interrupts, and serial communication. **(Applying-L3)**
CO4: Develop Arduino-based applications using Arduino IDE, libraries, and firmware programming concepts. **(Applying-L3)**
CO5: Analyze interfacing techniques for sensors, actuators, communication modules, and control systems using Arduino platforms. **(Analyzing-L4)**

UNIT-I
INTRODUCTION TO MICROCONTROLLERS AND AVR: Microcontrollers and embedded processors, overview of the AVR family, AVR Architecture, RISC architecture, ATMEGA 328p features, data memory, Status registers, program counter, data format and directives

UNIT-II
ASSEMBLY LANGUAGE PROGRAMMING: Introduction to AVR assembly programming, I/O programming, I/O bit manipulation instructions, Branch instructions and loop instructions, addressing modes.

UNIT-III
AVR PROGRAMMING IN C: Data types and I/O programming in C, Logic operation and memory allocation in C Programming timer and counters, programming interrupt (external and timer), serial port programming.

UNIT-IV
BASICS OF ARDUINO AND PROGRAMMING: Arduino family, Hardware prototyping, Arduino software architecture, Arduino integrated development environment (IDE), Arduino drivers.

Introduction to programming, Arduino native library and other libraries, Basic development steps, Serial monitor.

UNIT-V

SENSING WITH DIGITAL INPUTS: Different types of switches, debounce concept, Wires, the pull-up and pull-down concept, types of sensors, Digital and analog concepts, pseudo code for LED on/off, reading analog inputs, Sharp GP2Y0A02YK infrared long range sensor with Arduino, interfacing CD4051B multiplexer with Arduino, Firmware controlling the stepper motor, Coding the firmware for Bluetooth.

Text Books:

1. S. Naimi, S. Naimi, and M. A. Mazidi, The AVR Microcontroller and Embedded Systems Using Assembly and C. MicroDigitalEd.com, 2017.
2. J. Bayle, C Programming for Arduino. Packt Publishing Ltd, 2013.

Reference Books:

1. Programming and Customizing the AVR Microcontroller, D. V. Gadre, *Programming and Customizing the AVR Microcontroller*, McGraw-Hill Education.
2. Arduino Cookbook, Michael Margolis, *Arduino Cookbook*, 3rd Edition, O'Reilly Media, 2020.
3. Embedded C Programming and the Atmel AVR, Richard H. Barnett, Larry O'Cull, and Sarah Cox, *Embedded C Programming and the Atmel AVR*, Cengage Learning.
4. Exploring Arduino, Jeremy Blum, *Exploring Arduino: Tools and Techniques for Engineering Wizardry*, Wiley Publications.

M.Tech. (I Sem.) D251BDA2- ROBOT SAFETY AND MAINTENANCE

L	T	P	C
3	0	0	3

Prerequisites

Students should have basic knowledge of Robotics, Reliability Engineering, engineering mathematics, probability and statistics, manufacturing systems, and industrial safety practices. Familiarity with automation systems, sensors, actuators, and maintenance concepts will help students understand robot safety, reliability assessment, and maintenance strategies effectively.

Course Educational Objectives (CEOs)

The course is designed to provide students with comprehensive knowledge of robot safety, reliability analysis, and maintenance practices used in modern robotic systems and industrial automation. The students will develop the ability to analyze reliability configurations, safety assessment techniques, and maintenance strategies for robotic systems. The course also aims to enhance understanding of ergonomic factors, accident prevention methodologies, and safety standards to ensure safe human–robot interaction and efficient robotic system operation in industrial environments.

Course Outcomes: At the end of the course, the student will be able to

CO1: Analyze robot systems and apply mathematical concepts for reliability and safety design in robotic applications. **(Analyzing-L4)**

CO2: Analyze reliability configurations, failure analysis methods, and safety assessment techniques for robotic systems. **(Analyzing-L4)**

CO3: Evaluate safety features, safeguards, and operational practices in robotic systems and industrial environments. **(Evaluating-L5)**

CO4: Analyze maintenance strategies, diagnostic methods, and safety guidelines for robotic systems**. (Analyzing-L4)**

CO5: Analyze ergonomic factors, human–robot interaction, and root causes of robot-related accidents for improving workplace safety. **(Analyzing-L4)**

UNIT-I

Overview of Robot Safety and Reliability: Evolution and importance of robot safety in modern industries. Key facts, figures, and case studies on robot-related accidents. Scope and challenges in ensuring robot reliability and safety. Basic classification of robot systems and their applications. Overview of standards and regulations in robot safety. Basic Terminology and Mathematical Foundations: Definitions: reliability, safety, redundancy, and error recovery. Mathematical tools for reliability analysis (Boolean algebra, probability). Introduction to probability distributions relevant to robot systems. Overview of Laplace transforms for reliability calculations. Applications of mathematical concepts in safety design.

UNIT-II

Reliability Configurations and Failure Analysis: Series, parallel, and k-out-of-n system reliability configurations. Understanding failure density and hazard rate functions. Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR). Introduction to Failure Modes and Effects Analysis (FMEA). Practical applications of FMEA in robotic systems. Safety Analysis Techniques: Basics of Fault Tree Analysis (FTA) and probability evaluation. Hazard and Operability Studies (HAZOP) for robot safety. Interface safety analysis in integrated robot systems. Markov methods for reliability and safety assessment. Advantages and disadvantages of key safety analysis methods.

UNIT-III

Safety in Design and Operation: Safety considerations during the design phase of robots. Safety measures in robot installation and programming. Safe operation and maintenance practices for robotic systems. Responsibilities of manufacturers and end-users in safety. Understanding weak points in robot design and operations. Robot Safeguards and Safety Features: Physical safeguards: barriers, warning signs, and protective enclosures. Intelligent safety systems and their applications. Common robot safety features and their functions. Safety measures for robotic welding (laser, gas-shielded arc, resistance). Emergency procedures and fault recovery systems.

UNIT-IV

Maintenance of Robot Systems Types and Tools for Maintenance: Categories of robot maintenance: preventive, predictive, and corrective. Common tools and measuring instruments for robot inspection. Diagnostic approaches for robot systems. Periodic maintenance schedules and their benefits. Examples of maintenance practices in industrial robots. Maintenance Safety Guidelines: Guidelines for safeguarding maintenance personnel. Safe shutdown and start-up procedures during maintenance. Safety considerations for hydraulic and electric robots. Preventive measures for reducing maintenance-related accidents. Risk management during robot inspections and repairs.

UNIT-V

Ergonomic Factors in Robot Workplaces: Worker-machine interaction in robotic environments. Importance of worker training and ergonomic considerations. Job design to accommodate robotic automation. Role of communication between workers and management. Challenges of human-robot collaboration. Accident Analysis and Prevention: Root cause analysis of robot-related accidents. Common causes and sources of robot accidents. Recommendations to prevent human injuries. Understanding and applying robot-related safety standards. Methods for estimating accident probabilities and improving safety.

Text Book:

1. B. S. Dhillon, Robot System Reliability and Safety: A Modern Approach. Boca Raton, FL, USA: CRC Press, 2015.
2. Robot System Reliability and Safety: A Modern Approach, B. S. Dhillon, *Robot System Reliability and Safety: A Modern Approach*, CRC Press, Boca Raton, FL, USA, 2015.
3. Industrial Robotics: Technology, Programming and Applications, Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, and Nicholas G. Odrey, *Industrial Robotics: Technology, Programming and Applications*, McGraw-Hill Education.

Reference Books:

1. Safety, Security, and Reliability of Robotic Systems, B. B. Gupta and N. Nedjah (Eds.), *Safety, Security, and Reliability of Robotic Systems*, CRC Press, Boca Raton, FL, USA, 2023.
2. Maintenance Engineering Handbook, Keith Mobley, *Maintenance Engineering Handbook*, McGraw-Hill Education.
3. Robotics and Automation Handbook, T. R. Kurfess (Ed.), *Robotics and Automation Handbook*, CRC Press, Boca Raton, FL, USA, 2005.
4. Engineering Maintenance: A Modern Approach, B. S. Dhillon, *Engineering Maintenance: A Modern Approach*, CRC Press.

M.Tech. (I Sem.)	D251BDA3- EMBEDDED PROCESSOR ARCHITECTURE	L	T	P	C
		3	0	0	3

PREREQUISITES

Students should have basic knowledge of Computer Fundamentals, digital electronics, logic design, and programming concepts. Familiarity with microprocessors, binary arithmetic, memory organization, and computer programming fundamentals will help students understand embedded processor architecture and computer organization concepts effectively.

COURSE EDUCATIONAL OBJECTIVES (CEOS)

The course is designed to provide students with comprehensive knowledge of embedded processor architecture, computer organization, and memory hierarchy concepts used in modern computing systems. The students will develop the ability to understand processor structures, control unit design, arithmetic algorithms, and input/output organization techniques used in embedded and parallel computing environments. The course also aims to enhance analytical skills in pipelining, multiprocessor synchronization, and performance-oriented processor architectures for embedded and real-time applications.

Course Outcomes: At the end of the course the student will be able to

CO1: Apply the concepts of computer structure, instruction formats, addressing modes, and control unit organization in embedded processor systems. **(Applying-L3)**

CO2: Analyze microprogrammed control units, RISC/CISC architectures, and memory hierarchy techniques in computer systems. **(Analyzing-L4)**

CO3: Analyze fixed-point and floating-point arithmetic algorithms used in embedded processor architectures. **(Analyzing-L4)**

CO4: Classify and analyze various input/output organization and data transfer techniques in embedded systems. **(Analyzing-L4)**

CO5: Analyze pipelining concepts, multiprocessor architectures, inter-processor communication, and synchronization techniques. **(Analyzing-L4)**

UNIT-I

BASIC STRUCTURE OF COMPUTERS: Structure and function, Computer components: Bus interconnection, bus and memory transfer, Stack organization, Instruction formats, Instruction Cycle, Addressing modes, Program Control.

UNIT-II

MICROPROGRAMMED CONTROL: Control Memory, Address Sequencing, Micro Program examples, Design of control unit, RISC, CISC. MEMORY ORGANIZATION: Memory Hierarchy, Main Memory, Auxiliary Memory, Associate memory, Cache, Virtual Memory, Augmented Memory.

UNIT-III

COMPUTER ARITHMETIC: Fixed-point, Floating-point representation, Fixed point- Addition and subtraction with signed magnitude, and signed 2's complement data, multiplication Algorithm for signed magnitude data, Booth's multiplication algorithm, Division Algorithm for signed magnitude data; Floating point arithmetic operations- Addition and subtraction.

UNIT-IV

INPUT/OUTPUT ORGANIZATION: Peripheral Devices- keyboard/monitor, disk drive, I/O interface, Asynchronous/synchronous data transfer, Modes of transfer, priority Interrupt, Programmed I/O, Interrupt driven I/O, DMA.

UNIT-V

PIPELINING: Parallel Processing, Pipelining, Arithmetic Pipeline, Instruction Pipeline, RISC Pipeline, Vector Processing. MULTI PROCESSORS: Characteristics of Multiprocessors, Inter-processor Arbitration, Inter-processor communication and synchronization.

Text Books

1. Computer System Architecture, M. M. Mano, *Computer System Architecture*, Revised 3rd Edition, Prentice Hall of India Pvt. Ltd., New Delhi, India, 2023.
2. Computer Architecture and Organization, W. Stallings, *Computer Architecture and Organization*, 11th Edition, Pearson Education, 2022.

Reference Books

1. Computer Organization and Embedded Systems, C. Hamacher, Z. Vranesic, S. Zaky, and N. Manjikian, *Computer Organization and Embedded Systems*, 6th Edition, McGraw-Hill, New York, NY, USA, 2023.
2. Structured Computer Organization, A. S. Tanenbaum, *Structured Computer Organization*, 6th Edition, Pearson Education India, 2016.

M.Tech. (I Sem.)	D251BDB0- NATURAL LANGUAGE PROCESSING FOR ROBOTS	L	T	P	C
		3	0	0	3

PRE-REQUISITES

Basics of Artificial Intelligence, Python Programming, Machine Learning, and Fundamentals of Robotics.

COURSE EDUCATIONAL OBJECTIVES (CEOs)

The course is designed to provide students with fundamental knowledge of Natural Language Processing and speech processing techniques used in intelligent robotic systems. The students will develop the ability to perform text preprocessing, language modeling, and text representation for NLP-based applications. The course also aims to enable students to design and develop intelligent dialog systems and chatbots for effective human–robot interaction using machine learning and conversational AI techniques in advanced robotic applications.

COURSE OUTCOMES

At the end of the course, the student will be able to:

CO1: Apply the fundamentals, phases, and applications of Natural Language Processing in robotic and intelligent systems. **(Applying-L3)**

CO2: Apply speech processing, text preprocessing techniques, and language models used in Natural Language Processing applications. **(Applying-L3)**

CO3: Apply text representation and embedding techniques to convert textual data into meaningful vector representations for NLP applications. **(Applying-L3)**

CO4: Analyze information extraction methods and design dialog systems for robotic and conversational AI applications. **(Analyzing-L4)**

CO5: Evaluate chatbot systems for effective human–robot interaction using NLP and conversational AI techniques. **(Evaluating-L5)**

UNIT-I: Introduction to NLP

Introduction to Natural Language Processing, Applications of NLP, Challenges in NLP, NLP in Human–Robot Interaction, Basic Approaches to NLP, Phases of NLP, Feature Engineering, Building NLP Models, Evaluation Techniques for NLP Models.

UNIT-II: Speech and Language Processing

Speech Recognition and Speech Synthesis, Traditional and Deep Learning Approaches, Speech-to-Text Systems, Evaluation Metrics, Language Models, Text Preprocessing Techniques, Tokenization, Stop-word Removal, Stemming, Lemmatization, Part-of-Speech (POS) Tagging.

UNIT-III: Text Representation

Vector Space Models, Purpose and Importance of Text Representation, One-Hot Encoding, Bag-of-Words, Bag-of-N-grams, TF-IDF, Advantages and Limitations of Basic Vector Models, Distributed Representations, Word Embeddings, Word2Vec, CBOW, Skip-Gram, GloVe, Introduction to Transformer-based Embeddings.

UNIT-IV: Information Extraction and Dialog Systems

Information Extraction Applications, Keyphrase Extraction, Named Entity Recognition, Relation Extraction, Sentiment Analysis, Intent Recognition, Chatbots and Conversational AI, Applications of Chatbots, Taxonomy of Chatbots, FAQ Bots, Flow-based Bots, Open-ended Bots, Dialogue Management, Pipeline for Building Dialog Systems.

UNIT-V: Building Chatbots for Robotic Applications

Understanding Intents and Entities, Designing Conversational Flow, Listing Intents and Entities for Robotic Scenarios, Adding Utterances and Default Responses, User Interaction and Response Generation, Context-aware Conversation Handling, Voice-enabled Robotic Assistants, Case Study: Service Robot Chatbot / Smart Assistant Robot.

TEXT BOOKS

1. S. Vajjala, B. Majumder, A. Gupta, and H. Surana, *Practical Natural Language Processing*, O'Reilly Media Inc., 2021.
2. S. Raj, *Building Chatbots with Python: Using Natural Language Processing and Machine Learning*, Apress, 2019.

REFERENCE BOOKS

1. D. Jurafsky and J. H. Martin, *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition*, 2nd Edition, Prentice Hall, 2009.
2. C. Manning and H. Schütze, *Foundations of Statistical Natural Language Processing*, MIT Press, 1999.
3. J. Allen, *Natural Language Understanding*, Benjamin/Cummings Publishing Company Inc.
4. S. Bird, E. Klein, and E. Loper, *Natural Language Processing with Python*, O'Reilly Media, 2009.

ONLINE RESOURCES

1. NLTK Documentation
2. spaCy Documentation
3. Hugging Face Transformers
4. TensorFlow NLP Tutorials
5. Stanford NLP Group

M.Tech. (I Sem.)	D251BDB1- INTRODUCTION TO QUANTUM TECHNOLOGIES	L	T	P	C
		3	0	0	3

Pre-requisites: Students should have basic knowledge of engineering mathematics, linear algebra, probability concepts, and fundamentals of physics. Familiarity with basic computing concepts and programming fundamentals will help students understand quantum algorithms, quantum circuits, and computational models effectively.

Course Educational Objectives:

The course is designed to provide students with fundamental knowledge of Quantum Mechanics and its mathematical foundations relevant to modern engineering applications. The course aims to develop understanding of quantum computing, quantum communication, and quantum information processing concepts, along with quantum phenomena such as superposition, entanglement, and interference. It also enables students to analyze practical implementations, hardware platforms, and limitations of quantum systems while exploring emerging applications in computing, cryptography, sensing, and advanced quantum technologies.

Course Outcomes: After completion of the course, students should be able to

CO1: Apply the core principles of quantum mechanics and their technological implications in modern quantum systems. **(Applying-L3)**

CO2: Analyze quantum phenomena such as superposition, entanglement, and interference in quantum information systems. **(Analyzing-L4)**

CO3: Apply mathematical tools and quantum formalism to model and solve quantum mechanical systems. **(Applying-L3)**

CO4: Apply the concepts of quantum algorithms, quantum gates, and quantum circuits in quantum computing applications. **(Applying-L3)**

CO5: Analyze applications, implementation challenges, and future prospects of quantum communication, sensing, and quantum technologies. **(Analyzing-L4)**

UNIT – I

FUNDAMENTALS OF QUANTUM MECHANICS: Historical background: Blackbody radiation, photoelectric effect, and Compton scattering; Dual nature of light and matter; De Broglie hypothesis; Schrödinger equation; Free particle, infinite potential well, step potential; Operators and observables: position, momentum, Hamiltonian; Commutation relations and uncertainty principle; Quantum postulates and measurement theory; Eigen values, eigen functions.

UNIT – II

QUANTUM INFORMATION THEORY: Classical vs. quantum information; Qubit representation using Bloch sphere; Quantum superposition and quantum entanglement; Dirac notation (bra-ket), tensor products, and composite systems; Bell states and EPR paradox; Quantum gates: Pauli-X, Y, Z; Hadamard; Phase; T; CNOT; Quantum circuit models and notation; Measurement in computational basis; Quantum teleportation and no-cloning theorem; Quantum state tomography (introductory)

UNIT – III

QUANTUM COMPUTING: Classical computing review and limitations; Quantum parallelism and interference; Deutsch and Deutsch-Jozsa algorithms; Grover's search algorithm, Oracle and amplitude amplification; Shor's factoring algorithm (overview and significance); Quantum Fourier Transform (QFT); Quantum error correction: Bit-flip, phase-flip, and Shor's 9-qubit code; Introduction to quantum programming: Qiskit, Cirq, IBM Quantum Experience (overview)

UNIT – IV

QUANTUM COMMUNICATION: Introduction to quantum cryptography; Quantum key distribution (QKD): BB84 protocol; Entanglement-based QKD: Ekert protocol (E91); Eavesdropping and security of QKD; Quantum teleportation (circuit and protocol); Quantum dense coding; Quantum networks and entanglement swapping; Role of quantum repeaters; Single-photon sources and detectors; Implementation challenges (loss, decoherence, noise)

UNIT – V

QUANTUM TECHNOLOGIES AND APPLICATIONS: QUANTUM SENSORS: magnetometry, gravimetry; Quantum metrology: standard time, atomic clocks; Quantum imaging and lithography; Quantum materials: topological insulators, graphene, quantum dots; NV centers in diamonds for sensing; Hardware platforms: Superconducting qubits, Trapped ions, Photonic quantum processors; Quantum supremacy and NISQ era; Global initiatives: IBM, Google, D-Wave, IonQ, India's NQM; Ethical concerns and future prospects

Text Books

1. Quantum Computation and Quantum Information, Michael A. Nielsen and Isaac L. Chuang, *Quantum Computation and Quantum Information*, 10th Anniversary Edition, Cambridge University Press, 2010.
2. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, *Quantum Mechanics: Concepts and Applications*, 2nd Edition, Wiley Publications, 2009.

Reference Books

1. Introduction to Quantum Mechanics, David J. Griffiths and Darrell F. Schroeter, *Introduction to Quantum Mechanics*, 3rd Edition, Cambridge University Press, 2018.
2. Quantum Computing for Computer Scientists, Noson S. Yanofsky and Mirco A. Mannucci, *Quantum Computing for Computer Scientists*, Cambridge University Press, 2008.
3. Quantum Computing: An Applied Approach, Jack D. Hidary, *Quantum Computing: An Applied Approach*, Springer Publications, 2019.
4. Principles of Quantum Computation and Information, Giulio Casati and Giuliano Benenti, *Principles of Quantum Computation and Information*, World Scientific Publishing, 2007.

M.Tech. (I Sem.)	D251BDB2- KNOWLEDGE ENGINEERING AND EXPERT SYSTEMS	L	T	P	C
		3	0	0	3

Prerequisites:
Students should have basic knowledge of Artificial Intelligence, programming concepts, data structures, logic and reasoning, database systems, and fundamentals of computer science. Familiarity with AI programming languages, algorithms, and problem-solving techniques will help students understand knowledge representation and expert system development effectively.

Course Educational Objectives (CEOs): The course is designed to provide students with comprehensive knowledge of knowledge engineering principles and expert system technologies used in intelligent decision-making applications. The students will develop the ability to acquire, represent, organize, and reason with knowledge from different sources using rule-based and logic-based approaches. The course also aims to equip students with practical skills in designing and developing expert systems using AI languages, shells, and uncertainty-handling techniques for solving real-world engineering and industrial problems.

Course Outcomes: At the end of the course the student will be able to

CO1: Apply the foundational concepts of knowledge engineering and expert systems in intelligent problem-solving environments. **(Applying-L3)**

CO2: Demonstrate the ability to represent, organize, and reason with knowledge obtained from structured and unstructured sources. **(Applying-L3)**

CO3: Develop expert system prototypes using inference mechanisms, AI languages, and expert system shells. **(Applying-L3)**

CO4: Analyze data and apply plausible reasoning techniques to handle uncertainty in expert systems. **(Analyzing-L4)**

CO5: Evaluate different knowledge engineering approaches, production-rule programming techniques, and real-world expert system case studies**. (Evaluating-L5)**

UNIT-I

Introduction to Knowledge – Knowledge units, facts, concepts, relations. History of knowledge-based expert systems, Types of Knowledge based systems, Characteristics of current expert systems, Basic concepts for building expert systems. Knowledge Processes – acquisition, representation, reasoning, storing, sharing, reuse. Knowledge Cycle – Acquire, Represent, Store, Share, Hybridization (TextBook1).

UNIT-II

Knowledge sources– structured, semi-structured, unstructured. Knowledge Representation & Reasoning- Logic, Rules & representation, Developing Rules based system & Semantic Networks, Knowledge Acquisition, Knowledge representation schemes. Procedural Control of Reasoning and Rules - Horn Clauses, SLD resolution, Computing SLD derivations. (TextBook1)

UNIT-III

Building the Expert System, architecture of expert systems, Constructing an expert system, methods of inference. Expert systems shells, Development of environments, Use of AI Language. (TextBook2)

UNIT-IV

Conceptual data analysis; plausible reasoning techniques, Tools for building expert systems. Reasoning under uncertainty, Introduction to Clips, Pattern matching, Modular design and execution control. (TextBook2)

UNIT-V

Production-rule programming, Issues and case studies. Comparing different Approaches. Language and Tools for Knowledge Engineering, Expert system design examples, A Case Study in Knowledge Engineering. (TextBook2)

Text Books

1. An Introduction to Knowledge Engineering, S. Kendal and M. Creen, *An Introduction to Knowledge Engineering*, Springer Publishers, 2007.
2. Expert Systems: Principles and Programming, J. C. Giarratano and G. D. Riley, *Expert Systems – Principles & Programming*, 3rd Edition, Course Technology Publishers.

Reference Books

1. Building Expert Systems with Production Rules: The MYCIN Experiments, B. G. Buchanan and E. H. Shortliffe, *Building Expert Systems with Production Rules: The MYCIN Experiments*, Addison-Wesley Publishing Company.
2. Knowledge-Based Systems in Artificial Intelligence, R. Davis and D. B. Lenat, *Knowledge-Based Systems in Artificial Intelligence*, McGraw-Hill International Book Company.
3. Building Expert Systems, F. Hayes-Roth, D. A. Waterman, and D. B. Lenat (Eds.), *Building Expert Systems*, Addison-Wesley Publishing Company, Inc.
4. Expert Systems: State of the Art, I. S. Torsun, *Expert Systems: State of the Art*, Addison-Wesley Publishing Company.

M.Tech. (I Sem.) **D251BDB3- DESIGN OF EXPERIMENTS**

L	T	P	C
3	0	0	3

Pre-requisites: Probability and Statistics, Mathematics

COURSE EDUCATIONAL OBJECTIVES (CEOs): This course covers experimental data analysis, probability, sampling, design of experiments, regression analysis, and parameter optimization techniques.

COURSE OUTCOMES (COs): After the completion of this course, the student will be able to:
CO1: Apply the fundamentals of Design of Experiments (DOE) and relevant software tools for engineering applications. **(Applying-L3)**
CO2: Apply the concepts of random variables, probability distributions, and statistical methods in experimental strategies. **(Applying-L3)**
CO3: Analyze experimental data using sampling techniques and statistical analysis methods. **(Analyzing-L4)**
CO4: Design and conduct experiments involving single-factor and multi-factor experimental models. **(Analyzing-L4)**
CO5: Apply regression analysis and response surface methodology for optimization of engineering and process parameters. **(Applying-L3)**

UNIT-I
INTRODUCTION: Strategy of experimentation, some typical applications of experimental design, Basic principles, Guidelines for designing experiments, a brief history of statistical design, using statistical design in experimentation. DOE relevant Software's, Need of DOE software's.

UNIT-II
RANDOM VARIABLES: Definition attributes of a random variable, types of random variables, examples DISCRETE RANDOM VARIABLES: Introduction, probability distributions and probability mass functions, cumulative distribution function, mean and variance of a discrete random variable, Binomial and Poisson distribution.
CONTINUOUS RANDOM VARIABLES: Introduction, probability distributions and probability density functions, cumulative distribution function, mean and variance of a continuous random variable, normal distribution.

UNIT-III
SIMPLE COMPARATIVE EXPERIMENTS: Introduction, Basic statistical concepts, Sampling and Sampling Distribution, Inferences about the Differences in means, randomized designs, paired comparison Designs, Inferences about the Variances of Normal Distributions.

UNIT-IV
DESIGN AND ANALYSIS OF EXPERIMENTS WITH SINGLE FACTOR: Basic principles and guidelines of design of experiments, single factor experiments, Analysis of Variance (ANOVA), block design
DESIGN AND ANALYSIS OF EXPERIMENTS WITH MULTIPLE FACTORS: Introduction to Factorial design, the two factor factorial design, general factorial design, 2k factorial designs, confounding and blocking in factorial designs

UNIT-V

REGRESSION ANALYSIS: Introduction, simple linear regression analysis, multiple linear regression model, model adequacy checking.

RESPONSE SURFACE METHODOLOGY: Response surface methodology, parameter, optimization, robust parameter design and its application to control of processes with high variability.

REFERENCES:

1. Applied Statistics and Probability for Engineers, Douglas C. Montgomery and George C. Runger, *Applied Statistics and Probability for Engineers*, 7th Edition, John Wiley & Sons, 2018.
2. Design and Analysis of Experiments, Douglas C. Montgomery, *Design and Analysis of Experiments*, 10th Edition, John Wiley & Sons, 2019.
3. Introduction to Linear Regression Analysis, Douglas C. Montgomery, Elizabeth A. Peck, and G. Geoffrey Vining, *Introduction to Linear Regression Analysis*, 5th Edition, John Wiley & Sons, 2012.

REFERENCE BOOKS:

1. Statistical Design and Analysis of Experiments, Robert L. Mason, Richard F. Gunst, and James L. Hess, Statistical Design and Analysis of Experiments: With Applications to Engineering and Science, 2nd Edition, John Wiley & Sons, 2003.
2. Response Surface Methodology, Raymond H. Myers, Douglas C. Montgomery, and Christine M. Anderson-Cook, Response Surface Methodology: Process and Product Optimization Using Designed Experiments, 4th Edition, John Wiley & Sons, 2016.
3. Engineering Statistics, Douglas C. Montgomery, George C. Runger, and Norma F. Hubele, Engineering Statistics, 5th Edition, John Wiley & Sons, 2011.

M.Tech. (II Sem.)	D252BD01- ROBOT MOTION ANALYSIS AND CONTROLS	L	T	P	C
		3	1	0	4

PRE-REQUISITES: Engineering Mechanics, Theory of Machines, Principles of Robotics

Course Educational Objectives (CEO)

The course is designed to provide students with fundamental knowledge of coordinate transformations, kinematics, dynamics, trajectory planning, and control of robotic manipulators. The students will develop the ability to analyze robotic motion, derive kinematic and dynamic models, and apply trajectory planning techniques for robotic automation applications. The course also aims to enhance analytical and problem-solving skills in manipulator control using classical control strategies and modern simulation tools for robotics engineering applications.

Course Outcomes: At the end of the course, the student will be able

CO1: Apply composite transformations to represent coordinate frames and vectors in robotic systems. **(Applying-L3)**

CO2: Analyze forward and inverse kinematics for different types of serial robotic manipulators. **(Analyzing-L4)**

CO3: Analyze Jacobian matrices and dynamic models of robotic manipulators using Lagrangian mechanics. **(Analyzing-L4)**

CO4: Apply trajectory planning techniques for robotic motion control in joint space and Cartesian space. **(Applying-L3)**

CO5: Apply P, PI, PD, and PID control strategies for robotic manipulator control systems. **(Applying-L3)**

UNIT–I: Coordinate Frames, Mapping and Transformation

Coordinate frames, mapping and transformation: Coordinate frames - mapping, mapping between rotated frames, translated frames and both. Description of objects in space. Transformation of vectors- rotation and translation of vectors, combining rotation and translation of vectors, homogeneous transformation, composite transformation. Euler angle representations. Problems on transformation of vectors and frames.

UNIT–II: Forward and Inverse Kinematics

Forward and inverse kinematics: Description of links and joints, Denavit Hartenberg notation, kinematic relationship between adjacent links, manipulator transformation matrix, problems on kinematic modeling of 2 and 3 DoF serial robot configurations; inverse kinematics -manipulator workspace, solvability, multiple solutions, closed form solutions, inverse kinematics problems for 2 and 3 DoF serial robots.

UNIT–III: Differential Motion and Dynamic Modeling

Differential motion: Linear and angular velocity of a rigid body, combined linear and angular motion, manipulator Jacobian, Jacobian for prismatic and rotary joint, Jacobian singularities, velocity and Jacobian calculations for 2 DoF serial planar robot. Dynamic modeling: Lagrangian mechanics, 2 DoF manipulator dynamic model, Lagrange Euler formulation - generalized coordinates, kinetic energy, potential energy, equations of motion. Problems for 1 and 2 DoF R-R robots.

UNIT–IV: Trajectory Planning

Trajectory planning: Terminology in trajectory planning, steps in trajectory planning; path planning, skew motion, joint integrated motion; joint space techniques – use of P-degree polynomial as interpolation function, cubic polynomial trajectories, Cartesian space techniques; joint space versus Cartesian space trajectory planning, problems on cubic polynomial.

UNIT–V: Control of Manipulators

Control of manipulators: open and close-loop control, manipulator control problem, linear control schemes–P, D, I, PD, PID, characteristics of second order linear system, linear second order SISO model of a manipulator joint, partitioned PD control scheme, partitioned PID control scheme.

Text Book:

1. Robotics and Control, R. K. Mittal and I. J. Nagrath, *Robotics and Control*, 2nd Edition, Tata McGraw-Hill, New Delhi, India, 2008.

Reference Books:

1. Robotics, K. S. Fu, *Robotics*, McGraw-Hill, New York, NY, USA, 2004.
2. Introduction to Robotics: Mechanics and Control, John J. Craig, *Introduction to Robotics: Mechanics and Control*, 3rd Edition, Pearson Education, Boston, MA, USA, 2005.
3. Introduction to Robotics, S. K. Saha, *Introduction to Robotics*, 2nd Edition, Tata McGraw-Hill, New Delhi, India, 2014.

M.Tech. (II Sem.) D252BD02- ROBOT SENSORS AND ACTUATORS

L	T	P	C
3	1	0	4

PRE-REQUISITES: Basic Electronics, Measurements and Instruments

Students should have basic knowledge of Electronics, measurements and instrumentation, electrical systems, and fundamentals of robotics. Familiarity with transducers, signal conditioning, control systems, and basic mechanical systems will help students understand robotic sensing and actuation mechanisms effectively.

COURSE EDUCATIONAL OBJECTIVES (CEOs)

The course is designed to provide students with comprehensive knowledge of robotic sensors, actuators, microsensors, and microactuation technologies used in modern robotic systems. The students will develop the ability to analyze sensor characteristics, actuator performance, and motion transmission mechanisms for robotic applications. The course also aims to enhance understanding of sensor materials, microfabrication techniques, and intelligent sensing systems for the design and implementation of compact, reliable, and efficient robotic systems.

Course Outcomes: At the end of the course, the student will be able to:

CO1: Apply the working principles and characteristics of various robotic sensors and transducers used in robotic systems. **(Applying-L3)**

CO2: Analyze the performance, characteristics, and suitability of different actuators for robotic applications. **(Analyzing-L4)**

CO3: Design sensor–actuator systems for specific robotic and automation tasks. **(Analyzing-L4)**

CO4: Evaluate microsensors and microactuators for compact and intelligent robotic systems. **(Evaluating-L5)**

CO5: Analyze sensor materials and microfabrication techniques used for sensing and actuation components. **(Analyzing-L4)**

UNIT–I: Sensors and Transducers

Sensors: Definition of a sensor and actuators, Difference between sensor and actuators. Measuring element characteristics: Range, resolution, sensitivity, error, repeatability, linearity, accuracy, impedance, backlash, response time, dead band. Signal transmission types: Pneumatic, hydraulic, electronic. Principle of operation, construction details, characteristics and applications of potentiometer, Proving Rings, Strain Gauges, Resistance thermometer, Thermistor, Hot-wire anemometer, Resistance Hygrometer, Photo-resistive sensor.

UNIT–II: Inductive and Capacitive Transducers

Inductive Transducer: Principle of operation, construction details, characteristics and applications of LVDT, Induction potentiometer, variable reluctance transducer, synchros, microsyn. Capacitive Transducers: Working principles, types, signal conditioning. Applications: Capacitor microphones, capacitive pressure sensors, proximity sensors.

UNIT–III: Actuators and Motion Transmission Systems

Types of actuators: Linear, rotary, logical, continuous. Pneumatic & electro-pneumatic actuators: Cylinders, rotary actuators. Hydraulic actuators: Control valves, types, selection. Electrical actuators: Solid-state switches, solenoids, DC/AC motors, stepper motors, synchronous motors, piezoelectric actuators. Motion transmission systems: Gear, belt, harmonic drives.

UNIT–IV: Microsensors and Microactuators

Types and principles of micro sensors: Definition of a micro sensor, differences between sensor and micro sensor, Pressure, position, acceleration, chemical, biosensors, temperature, flow. Actuation mechanisms: Shape memory effects (one-way, two-way, pseudo elasticity). Micro actuators: Electrostatic, magnetic, fluidic, inverse piezoelectric, and other principles.

UNIT–V: Sensor Materials and Fabrication Techniques

Sensor materials: Silicon, plastics, metals, ceramics, glass, nano-materials. Fabrication techniques: Vacuum deposition, sputtering, CVD, electroplating, photolithography, bulk and surface micromachining, LIGA process.

Text Books

1. Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators, and Algorithms, N. Correll, B. Hayes, C. Heckman, and A. Roncone, *Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators, and Algorithms*, MIT Press, 2022. *(Unit III and IV)*
2. Printed and Flexible Sensor Technology: Fabrication and Applications, R. Dahiya, *Printed and Flexible Sensor Technology: Fabrication and Applications*, Institute of Physics Publishing, 2021. *(Unit V)*
3. Handbook of Modern Sensors: Physics, Designs and Applications, J. Fraden, *Handbook of Modern Sensors: Physics, Designs and Applications*, 4th Edition, Springer, 2010. *(Unit I and II)*

Reference Books

1. The Mechatronics Handbook, R. H. Bishop, *The Mechatronics Handbook*, CRC Press, 2002.
2. Shape Memory Actuators, M. Kohl, *Shape Memory Actuators*, 1st Edition, Springer, 1997.
3. Sensors and Actuators, Ian Sinclair, *Sensors and Actuators*, 3rd Edition, Elsevier, 2012.
4. MEMS and Microsystems: Design and Manufacture, Tai-Ran Hsu, *MEMS and Microsystems: Design and Manufacture*, 2nd Edition, McGraw-Hill Education, 2008.

Web References:

1. http://www.societyofrobots.com/robot_tutorial.shtml#sensors.
2. https://www.cse.sc.edu/~yiannisr/574/2016Fall/Lectures/02-SensorsActuators.pdf.

M.Tech. (II Sem.)	D252BD03- ELECTRO MECHANICAL ACTUATION SYSTEMS	L	T	P	C
		3	1	0	4

PRE-REQUISITES

Engineering Mechanics, Electrical Machines, Control Systems, Mechatronics, Fundamentals of Robotics.

COURSE EDUCATIONAL OBJECTIVES (CEOs)

1. Provide fundamental knowledge of electromechanical actuators used in automation and robotic systems.
2. Develop understanding of electrical drives, motors, sensors, and transmission mechanisms.
3. Enable students to analyze actuator performance and control strategies.
4. Introduce advanced actuation technologies for industrial and robotic applications.

COURSE OUTCOMES (COs): At the end of the course, the student will be able to

CO1: Explain the principles and characteristics of various electromechanical actuators used in automation systems. **(Understanding-L2)**

CO2: Analyze the performance of DC, AC, stepper, and servo motor-based actuation systems. **(Analyzing-L4)**

CO3: Apply control techniques for precise motion and position control in robotic applications. **(Applying-L3)**

CO4: Evaluate sensors, feedback devices, and drive systems used in electromechanical actuation. **(Analyzing-L4)**

CO5: Apply electromechanical actuation systems for industrial and robotic applications. **(Applying-L3)**

UNIT – I: Fundamentals of Electromechanical Actuation

Introduction to Actuation Systems, Classification of Actuators, Principles of Electromechanical Energy Conversion, Force and Torque Generation, Static and Dynamic Characteristics of Actuators, Selection Criteria for Actuators, Applications in Robotics and Industrial Automation.

UNIT-II: Electric Motors for Actuation

DC Motors: Construction, Characteristics, Speed-Torque Relationships, Speed Control Methods.

AC Motors: Induction Motors, Synchronous Motors, Variable Frequency Drives (VFDs).

Stepper Motors: Types, Construction, Working Principle, Drive Circuits, Applications.

Servo Motors: AC and DC Servo Motors, Closed-Loop Position Control, Performance Characteristics.

UNIT – III: Sensors and Feedback Systems

Position Sensors: Potentiometers, Encoders, Resolvers. Velocity and Acceleration Sensors: Tachometers, Accelerometers. Force and Torque Sensors, Current and Voltage Sensors.

Feedback Principles, Open-Loop and Closed-Loop Systems, Signal Conditioning, Sensor Integration in Actuation Systems.

UNIT – IV: Drive Systems and Motion Control

Motor Drive Fundamentals, Power Electronic Converters, PWM Techniques, H-Bridge Circuits. PID Control for Actuation Systems, Motion Profiles, Trajectory Planning. Position, Speed, and Torque Control, Servo Drive Systems, Digital Motion Controllers, Robotic Joint Control.

UNIT – V: Advanced Actuation Systems and Applications

Linear Actuators, Voice Coil Actuators, Electromagnetic Actuators. Smart Actuators, Piezoelectric Actuators, Shape Memory Alloy (SMA) Actuators. Actuation Systems in Industrial Robots, Collaborative Robots (Cobots), Autonomous Vehicles, Medical Robotics, Aerospace and Precision Manufacturing Applications**.**

TEXT BOOKS

1. Hassan Khalil, *Nonlinear Systems and Control for Robotics and Automation*, Springer.
2. D. Patranabis, *Principles of Industrial Instrumentation*, McGraw Hill.
3. R. Krishnan, *Electric Motor Drives: Modeling, Analysis and Control*, Pearson.

REFERENCE BOOKS

1. W. Bolton, *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, Pearson.
2. K. Ogata, *Modern Control Engineering*, Pearson.
3. Saeed B. Niku, *Introduction to Robotics: Analysis, Control and Applications*, Wiley.
4. Austin Hughes and Bill Drury, *Electric Motors and Drives*, Elsevier.

ONLINE RESOURCES

1. NPTEL – Mechatronics and Industrial Automation
2. NPTEL – Electric Drives and Control
3. MATLAB/Simulink Documentation
4. ROS Control Documentation
5. Siemens Motion Control Learning Resources

M.Tech. (II Sem.)	D252BD90- PRODUCT LIFE CYCLE MANAGEMENT LAB	L	T	P	C
		0	1	2	2

Prerequisites:

Course Educational Objectives (CEOs): The course is designed to provide practical understanding of Product Lifecycle Management (PLM) tools and methodologies used in robotic and automation product development. The students will gain hands-on experience in managing engineering data, creating product structures and BOMs, handling revisions and engineering changes, and integrating design, manufacturing, and maintenance information within a collaborative PLM environment. The course also aims to develop the ability to analyze lifecycle issues such as sustainability, maintainability, traceability, and cost optimization for efficient robotic product development and lifecycle decision-making.

Course Outcomes: At the end of the course, the student will be able to

CO1: Use PLM tools to create, store, retrieve, and manage engineering data related to robotic products. **(Applying-L3)**

CO2: Explain product structures, BOMs, and configuration data for automation systems. **(Applying-L3)**

CO3: Apply revision control, workflow management, and engineering change procedures in a PLM environment. **(Applying-L3)**

CO4: Integrate design, manufacturing, and maintenance data for lifecycle decision-making in robotics applications. **(Applying-L3)**

CO5: Analyze lifecycle issues such as cost, sustainability, maintainability, and traceability in robotic product development. **(Analyzing-L4)**

LIST OF EXERCISES

1. Introduction to PLM Environment
2. Creation of Product Data for a Robotic System
3. CAD Data Management
4. Product Structure and BOM Creation
5. Version and Revision Management
6. Workflow and Approval Process
7. Engineering Change Management
8. Configuration Management
9. Document Management
10. Collaboration in Product Development
11. PLM Integration with Manufacturing
12. Lifecycle Analysis of a Robotic Product

Recommended Text / Reference Books

1. Stark, J., Product Lifecycle Management: 21st Century Paradigm for Product Realisation.
2. Saaksvuori, A. and Immonen, A., Product Lifecycle Management.
3. Ameri, F. and Dutta, D., literature on PLM integration and product data management.

M.Tech. (II Sem.) **D252BD91- ROBOTICS SIMULATION LAB**

L	T	P	C
0	1	2	2

PRE-REQUISITES: Principles of Robotics

Course Educational Objectives (CEO)

The course is designed to provide practical exposure to robotic kinematics, dynamics, workspace analysis, and mobile robot motion through simulation-based experiments. The students will develop the ability to model, analyze, and simulate robotic manipulators and wheeled mobile robots using modern robotics software tools. The course also aims to enhance problem-solving and analytical skills in robotic motion analysis, trajectory generation, dynamic simulation, and control of robotic systems for automation and research applications.

Course Outcomes: At the end of the course, the student will be able

CO1: Apply forward and inverse kinematic principles to analyze the motion of planar and spatial robotic manipulators. **(Applying-L3)**

CO2: Analyze the workspace and motion capabilities of planar and spatial robots using kinematic modeling techniques. **(Analyzing-L4)**

CO3: Apply Denavit–Hartenberg (DH) parameters to develop and simulate three-dimensional robotic models. **(Applying-L3)**

CO4: Analyze the dynamic behavior of planar manipulators and wheeled mobile robots using simulation techniques. **(Analyzing-L4)**

CO5: Apply kinematic and dynamic control techniques for differential, omnidirectional, and mecanum wheel drive robots. **(Applying-L3)**

LIST OF EXERCISES

Any twelve exercises from the following to be performed

1. Forward kinematic analysis of a 2R planar robot and 6-DoF robotic manipulators.
2. Inverse kinematic analysis of a 2R planar robot and 6-DoF robotic manipulators.
3. Workspace generation and analysis of planar robotic manipulators.
4. Workspace generation and analysis of spatial robotic manipulators.
5. Development of three-dimensional robotic models using Denavit–Hartenberg (DH) parameters.
6. Forward dynamic analysis of a 2R planar robotic manipulator.
7. Inverse dynamic analysis of a 2R planar robotic manipulator.
8. Kinematic simulation of differential wheel drive mobile robots.
9. Kinematic simulation of omnidirectional wheel drive mobile robots.
10. Kinematic simulation of mecanum wheel drive mobile robots.
11. Dynamic simulation of differential wheel drive mobile robots.
12. Dynamic simulation of omnidirectional wheel drive mobile robots.
13. Kinematic control of differential wheel drive mobile robots.
14. Kinematic control of omnidirectional wheel drive mobile robots.

Software / Simulation Tools

- Robo Analyzer
- MATLAB
- Simulink
- ROS *(optional integration)*

References:

1. RoboAnalyzer, RoboAnalyzer, IIT Delhi.
2. Wheeled Mobile Robots, NPTEL Course on Wheeled Mobile Robots, IIT Madras.
3. Introduction to Robotics: Mechanics and Control, John J. Craig, *Introduction to Robotics: Mechanics and Control*, 3rd Edition, Pearson Education, 2005.
4. Robot Modeling and Control, Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, Wiley Publications, 2020.

M.Tech. (II Sem.) **D252BDA0- MOBILE AND MICRO ROBOTS**

L	T	P	C
3	0	0	3

Prerequisites:

Students should have basic knowledge of Robotics, engineering mechanics, kinematics, dynamics, sensors, and control systems. Familiarity with embedded systems, basic programming, and automation concepts will help students understand mobile robot locomotion, navigation, sensing, and micro-robotic technologies effectively.

Course Educational Objectives (CEOs)

The course is designed to provide students with comprehensive knowledge of mobile robotics, locomotion systems, robotic perception, and micro-robotic technologies. The students will develop the ability to analyze kinematic and dynamic models of wheeled and omnidirectional robots, evaluate sensing systems for robotic perception, and understand the design and applications of micro-robots in industrial and biomedical domains. The course also aims to familiarize students with microfabrication techniques, implementation challenges, and future prospects of intelligent mobile and micro-robotic systems.

Course Outcomes: At the end of the course, the student will be able

CO1: Apply fundamental concepts to classify mobile robots and relate locomotion mechanisms to environmental challenges. **(Applying-L3)**

CO2: Evaluate kinematic and dynamic models of mobile robots with different locomotion systems. **(Evaluating-L5)**

CO3: Analyze the performance and selection of perception sensors used in mobile robotic systems. **(Analyzing-L4)**

CO4: Evaluate micro-robotic sensors, technologies, and applications in medicine, manufacturing, and industrial systems. **(Evaluating-L5)**

CO5: Recommend implementation strategies and microfabrication techniques for advanced mobile and micro-robotic systems. **(Evaluating-L5)**

UNIT–I: Introduction to Mobile Robots and Locomotion

Introduction to mobile robots - Tasks of mobile robots, robot's manufacturers, type of obstacles and challenges, tele-robotics, philosophy of robotics, service robotics, types of environment representation. Locomotion: - Introduction, key issues for locomotion, legged mobile robots, wheeled mobile robots, aerial mobile robots, underwater robots and surface robots.

UNIT–II: Mobile Robot Kinematics

Mobile robot kinematics: - Introduction, kinematic models and constraints, mobile robot maneuverability, mobile robot workspace (two, three, four - wheeled robots, omni-directional and macanum wheeled robots).

UNIT–III: Robot Dynamics and Perception

Robot dynamics: Introduction, general robot dynamic modeling, differential-drive WMR, three-wheel omnidirectional mobile robot, four mecanum-wheel omnidirectional robot. Perception: Sensors for mobile robots: sensor classification, characterizing sensor performance, representing uncertainty, wheel/motor sensors, heading sensors, accelerometers, inertial measurement unit (IMU), ground beacons, active ranging, motion/speed sensors, vision-based sensors.

UNIT–IV: Micro Robotics and Sensors

Micro robotics: Introduction, micro world, micro robots, in medicine, assembly heterogeneous components, material science, mobile micro robots, science and technology behind micro robots. Sensors in micro robots: Introduction, sensors terminology, sensing technologies for displacements, electromagnetic sensors, optical based displacement sensors, motion tracking with microscopes, scanning electron microscope.

UNIT–V: Implementation and Applications of Mobile and Micro Robots

Implementation, applications, and future prospects of mobile robots: Manufacturing requirements for microrobots. Overview of microfabrication principles: Surface micromachining and lithography-based processes, high-aspect ratio micromachining (electrodischarge machining, laser), design selection criteria. Surgical tools: Active endoscopes, microrobotics for cell biology.

TEXT BOOKS

1. Introduction to Autonomous Mobile Robots, R. Siegwart, I. R. Nourbakhsh, and D. Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd Edition, MIT Press, Cambridge, MA, USA, 2011. *(Units I, II, III)*
2. Microrobotics: Methods and Applications, Y. Bellouard, *Microrobotics: Methods and Applications*, CRC Press, Boca Raton, FL, USA, 2019. *(Units IV and V)*

REFERENCE BOOKS

1. Computational Principles of Mobile Robotics, G. Dudek and M. Jenkin, *Computational Principles of Mobile Robotics*, Cambridge University Press, Cambridge, U.K., 2010.
2. Autonomous Robots, G. A. Bekey, *Autonomous Robots*, MIT Press, Cambridge, MA, USA, 2005.
3. Microrobotics for Micromanipulation, N. Chaillet and S. Régnier, *Microrobotics for Micromanipulation*, Wiley Publications, Hoboken, NJ, USA, 2013.

M.Tech. (II Sem.) **D252BDA1 - MACHINE VISION**

L	T	P	C
3	0	0	3

PRE-REQUISITES

Fundamentals of Digital Image Processing, Linear Algebra, Probability and Statistics, Python Programming, and Basics of Machine Learning.

COURSE EDUCATIONAL OBJECTIVES (CEOs)

The course is designed to provide students with fundamental knowledge of digital image processing and computer vision techniques used in intelligent systems and robotic applications. The students will develop the ability to analyze image segmentation, feature extraction, object recognition, and motion analysis techniques for machine vision applications. The course also aims to introduce advanced deep learning approaches for object detection, image classification, and intelligent vision-based automation systems using modern computer vision frameworks and tools.

COURSE OUTCOMES

At the end of the course, the student will be able to:

CO1: Apply the fundamentals of digital image processing and image preprocessing techniques in machine vision systems. **(Applying-L3)**

CO2: Analyze various image segmentation and feature extraction techniques used in computer vision applications. **(Analyzing-L4)**

CO3: Apply three-dimensional vision and motion analysis techniques for intelligent computer vision applications. **(Applying-L3)**

CO4: Implement object recognition and pattern classification methods using machine learning techniques. **(Applying-L3)**

CO5: Develop deep learning-based object detection and image classification models for machine vision applications. **(Analyzing-L4)**

UNIT-I: Image Preprocessing

Elements of Digital Image Processing, Sampling and Quantization, Pixel Relationships, Spatial Filtering Techniques, Smoothing Filters, Median Filtering, Sharpening Techniques, Color Models, Morphological Operations, Dilation and Erosion, Opening and Closing, Convex Hull, Region Filling, Boundary Extraction.

UNIT-II: Image Segmentation

Introduction to Image Segmentation, Thresholding Techniques, Global Thresholding, Otsu's Thresholding Method, Edge-based Segmentation, Point Detection, Line Detection, Edge Detection, Canny Edge Detection, Region-based Segmentation, Region Growing, Split and Merge Techniques, Graph-cut Segmentation, Mean Shift Segmentation, Semantic Segmentation Basics, Fully Convolutional Networks (FCNs), Encoder–Decoder Architectures, U-Net Architecture, SegNet and Applications.

UNIT-III: 3D Vision and Motion Analysis

Basic Projective Geometry, 3D Vision Concepts, Shape from Shading, Photometric Stereo, Depth Estimation Techniques, Video Analysis, Motion Detection, Video Tracking, Background Modeling, Kalman Filter, Particle Filter, Motion Estimation and Tracking Applications.

UNIT-IV: Object Recognition and Pattern Analysis

Knowledge Representation, Statistical Pattern Recognition, Classification Principles, Classifier Design and Learning, Support Vector Machines, Cluster Analysis, Artificial Neural Networks, Feed Forward Networks, Unsupervised Learning, Hopfield Networks, Feature Extraction and Matching, Graph-based Recognition Methods, Recognition using Graph Matching Techniques.

UNIT-V: Deep Learning for Object Detection and Classification

Object Detection and Classification, YOLO Architecture (YOLOv3, YOLOv4, YOLOv5, YOLOv8 Overview), Bounding Boxes, Confidence Scores, Anchor Boxes, Intersection over Union (IoU), Mean Average Precision (mAP), Dataset Preparation using COCO and Pascal VOC, Training Custom YOLO Models, Deployment using OpenCV and PyTorch, Introduction to R-CNN, Fast R-CNN, Faster R-CNN, Mask R-CNN Architecture, Region Proposal Networks (RPN), Applications of Deep Learning in Machine Vision.

Text Books

1. Digital Image Processing, S. Jayaraman, S. Sakkirajan, and T. Veerakumar, *Digital Image Processing*, 2nd Edition, McGraw Hill, 2020.
2. Deep Learning for Computer Vision, R. Shanmugamani, *Deep Learning for Computer Vision*, Packt Publishing, 2018.
3. Digital Image Processing, A. Baskar, M. Rajappa, S. K. Vasudevan, and T. S. Murugesh, *Digital Image Processing*, CRC Press, Taylor & Francis Group, 2023.

Reference Books

1. Digital Image Processing, R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 4th Edition, Pearson Education, 2019.
2. Digital Image Processing: An Algorithmic Introduction, W. Burger and M. J. Burge, *Digital Image Processing: An Algorithmic Introduction*, 3rd Edition, Springer, 2016.
3. Computer Vision and Image Analysis, S. E. Umbaugh, *Computer Vision and Image Analysis*, 4th Edition, CRC Press, 2023.
4. Computer Vision: Algorithms and Applications, Richard Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2022.

ONLINE RESOURCES

1. YOLO Darknet Repository
2. Ultralytics YOLO Documentation
3. LearnOpenCV Tutorials
4. OpenCV Documentation
5. PyTorch Computer Vision Tutorials

M.Tech. (II Sem.)	D252BDA2 - DIGITAL SIGNAL & IMAGE PROCESSING	L	T	P	C
		3	0	0	3

Prerequisites: Students should have basic knowledge of Engineering Mathematics, signals and systems, linear algebra, and fundamentals of programming. Familiarity with Fourier analysis, matrices, and basic image representation concepts will help students understand digital signal and image processing techniques effectively.

Course Educational Objectives (CEOs)

The course is designed to provide students with comprehensive knowledge of digital signal processing and digital image processing techniques used in modern engineering applications. The students will develop the ability to analyze discrete-time signals and systems using transform-based methods and apply signal processing techniques for practical applications. The course also aims to enhance understanding of image enhancement, segmentation, compression, and morphological processing techniques for intelligent vision and multimedia systems.

Course Outcomes: At the end of the course, the student shall be able to

CO1: Apply the representation concepts of discrete-time signals and systems for signal analysis applications. **(Applying-L3)**

CO2: Apply suitable digital signal processing techniques for analysis of discrete-time signals and systems. **(Applying-L3)**

CO3: Apply image formation concepts, color models, and pixel relationship techniques in digital image processing applications. **(Applying-L3)**

CO4: Analyze spatial-domain and frequency-domain image enhancement techniques for image processing applications. **(Analyzing-L4)**

CO5: Apply image compression, segmentation, and morphological image processing techniques for intelligent image analysis applications. **(Applying-L3)**

UNIT–I: Discrete-Time Signals and Systems

Discrete Time Signals and Systems: Basics of signals – period, frequency, phase, a mathematical representation of signals. Discrete time signals and systems- sequences, linear shift-invariant systems, stability and causality and linear constant coefficient difference equations.

UNIT–II: Transform Analysis

Transform Analysis: Frequency domain representation of discrete time signals and systems, representation of discrete time signals by Fourier transform (DTFT), Discrete Fourier Transforms, Properties of DFT, Z transform, the region of convergence.

UNIT–III: Fundamentals of Digital Image Processing

FUNDAMENTALS OF DIGITAL IMAGE PROCESSING: Image fundamentals, types of Images based on energy source, Steps of Image Processing, Color Image and Color Models, Sampling and Quantization, Pixel Relationship -Neighbor and Adjacency.

UNIT–IV: Image Enhancement

IMAGE ENHANCEMENT: Basic Gray Level transformations, Histogram processing, basic spatial filtering operation for image smoothing, image edge detection using Robert, Sobel, Previtt masks, and Laplacian mask, image sharpening in spatial domain. Ideal low pass and high pass filter for frequency domain smoothing and sharpening.

UNIT–V: Image Compression and Segmentation

IMAGE COMPRESSION AND SEGMENTATION: Fundamentals of redundancies, Image compression models, lossy and lossless image compression techniques. Morphological operations, Image segmentation techniques.

Text Books

1. Theory and Applications of Digital Signal Processing, L. R. Rabiner and B. Gold, *Theory and Applications of Digital Signal Processing*, Prentice-Hall of India, 2015.
2. Digital Image Processing, R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 4th Edition, Pearson Education, 2018.

Reference Books

1. Understanding Digital Signal Processing, R. G. Lyons, *Understanding Digital Signal Processing*, 3rd Edition, Pearson Education India, 2011.
2. Digital Signal Processing, A. V. Oppenheim and R. W. Schafer, *Digital Signal Processing*, Prentice-Hall of India Pvt. Ltd., New Delhi, India, 2015.
3. Digital Signal Processing: Principles, Algorithms and Applications, J. G. Proakis and D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, 3rd Edition, PHI Learning, 2000.
4. Hands-On Image Processing with Python, S. Dey, *Hands-On Image Processing with Python*, Packt

M.Tech. (II Sem.) **D252BDA3 - MULTI AGENT SYSTEMS**

L	T	P	C
3	0	0	3

Prerequisites:

Students should have basic knowledge of Artificial Intelligence, data structures, algorithms, object-oriented programming, machine learning, and distributed systems. Familiarity with search techniques, optimization, and communication protocols will help students understand multi-agent coordination and distributed intelligent systems effectively.

Course Educational Objectives (CEOs)

The course is designed to provide students with comprehensive knowledge of intelligent agents, multi-agent architectures, distributed problem solving, and collaborative decision-making systems. The students will develop the ability to design agent communication protocols, implement distributed planning and learning strategies, and analyze coordination mechanisms in multi-agent environments. The course also aims to enhance understanding of distributed decision support systems and modern multi-agent development frameworks for intelligent and autonomous applications.

Course Outcomes: At the end of the course, the student will be able

CO1: Apply the concepts and architectures of intelligent agents in multi-agent environments. **(Applying-L3)**

CO2: Design and implement agent communication and interaction protocols for developing societies of intelligent agents. **(Applying-L3)**

CO3: Implement distributed problem-solving, planning, and search algorithms in multi-agent systems. **(Applying-L3)**

CO4: Analyze distributed decision-making techniques and implement learning strategies for adaptive coordination in multi-agent systems. **(Analyzing-L4)**

CO5: Analyze distributed decision-support models and multi-agent frameworks for real-world collaborative applications. **(Analyzing-L4)**

UNIT–I: Intelligent Agents

Intelligent Agents:-Introduction, Agents, Abstract Architectures for Intelligent Agents, Concrete Architectures for Intelligent Agents, Agent Programming Languages. (Chapter 1-TextBook1)

Deductive Reasoning Agents-RALPH Agent, Agents as Theorem Provers, Practical Reasoning Agent-Practical Reasoning Equals Deliberation Plus Means-Ends Reasoning, Means-Ends Reasoning, HOMER Agent. (Chapters 3,4-TextBook2)

UNIT–II: Reactive and Hybrid Agents

Reactive and Hybrid Agents-Brooks and the Subsumption Architecture, Limitations of Reactive Agents, Hybrid Agents-Touring Machines, InteRRaP.(Chapter 5-TextBook2)

Multiagent Systems and Societies of Agents: Introduction, Agent Communications, Agent Interaction Protocols, Societies of Agents. (Chapter 2-TextBook1)

UNIT–III: Distributed Problem Solving and Planning

Distributed Problem Solving and Planning: Introduction. Task Sharing, Result Sharing, Distributed Planning. Distributed Plan representations, Distributed Planning and Execution. (Chapter 3-TextBook1)

Search Algorithms for Agents: Introduction, Constraint Satisfaction, Path-Finding Problem, Two-Player Games. (Chapter 4-TextBook1)

UNIT–IV: Distributed Decision Making and Learning

Distributed Rational Decision Making: Introduction, Evaluation Criteria, Voting, Auctions, Bargaining, General Equilibrium Market Mechanisms, Contract Nets. (Chapter 5- TextBook1)

Learning in Multiagent Systems: Introduction, A General Characterization, Learning and Activity Coordination, Learning about and from Other Agents, Learning and Communication. (Chapter 6-TextBook1)

UNIT–V: Decision Support Systems and Multi-Agent Frameworks

Distributed Models for Decision Support: Decision support Systems, an Agent Architecture for Distributed Decision Support Systems, Application Case Studies—Environmental Emergency Management, Energy Management, Road Traffic Management. (Chapter 11-Textbook 1)

Developing Multi-Agent Systems with Frameworks: The JADE Platform-JADE and the agents paradigm, JADE architecture, Compiling the software and launching the platform, JADE packages, Message transport service, Admin and debugging tool, MESA Framework (Chapter 3-TextBook 3)

Text Books

1. Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence, G. Weiss, *Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence*, MIT Press, Cambridge, MA, USA, 2000.
2. An Introduction to Multiagent Systems, M. J. Wooldridge, *An Introduction to Multiagent Systems*, John Wiley & Sons, Hoboken, NJ, USA, 2002.

Reference Books

1. Multi-Agent Coordination: A Reinforcement Learning Approach, K. Sadhu and A. Konar, *Multi-Agent Coordination: A Reinforcement Learning Approach*, Wiley Publications, Hoboken, NJ, USA, 2020.
2. Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations, Y. Shoham and K. Leyton-Brown, *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations*, Cambridge University Press, Cambridge, U.K., 2008.
3. Multi-Agent Machine Learning: A Reinforcement Approach, H. M. Schwartz, *Multi-Agent Machine Learning: A Reinforcement Approach*, John Wiley & Sons, Hoboken, NJ, USA, 2014.
4. Programming Multi-Agent Systems in AgentSpeak using Jason, Rafael H. Bordini, Jomi F. Hübner, and Michael Wooldridge, *Programming Multi-Agent Systems in AgentSpeak using Jason*, Wiley Publications, 2007.

M.Tech. (II Sem.)	D252BDB0 - REINFORCEMENT LEARNING FOR ROBOTICS	L	T	P	C
		3	0	0	3

Prerequisites:

Students should have basic knowledge of Machine Learning, probability and statistics, linear algebra, optimization techniques, Python programming, and robotics fundamentals. Familiarity with neural networks, dynamic systems, and mathematical modeling will help students understand reinforcement learning algorithms and robotic learning applications effectively.

Course Educational Objectives (CEOs)

The course is designed to provide students with comprehensive knowledge of reinforcement learning principles and their applications in robotics and intelligent autonomous systems. The students will develop the ability to analyze decision-making models, learning strategies, and control policies using Markov Decision Processes, Monte Carlo methods, and Temporal-Difference learning approaches. The course also aims to enhance understanding of function approximation, policy optimization, and deep reinforcement learning techniques for robotic navigation, control, and intelligent behavior generation.

Course Outcomes: At the end of the course, the student will be able

CO1: Evaluate reinforcement learning models using Multi-Armed Bandits and Finite Markov Decision Processes for robotic applications. **(Evaluating-L5)**

CO2: Analyze policy evaluation and prediction methods using Monte Carlo and Temporal-Difference learning techniques in robotic tasks. **(Analyzing-L4)**

CO3: Evaluate tabular reinforcement learning methods and on-policy prediction techniques using approximation methods. **(Evaluating-L5)**

CO4: Analyze on-policy and off-policy control strategies with function approximation for improving robot learning performance. **(Analyzing-L4)**

CO5: Evaluate eligibility traces and policy gradient methods for optimization of robotic learning systems. **(Evaluating-L5)**

UNIT–I: Introduction to Reinforcement Learning

Introduction: Reinforcement Learning, Applications in robotics, Elements of Reinforcement Learning, Limitations and Scope.

Multi Armed Bandits: A n-Armed Bandit Problem, Action-Value Methods, Incremental implementation, tracking a non-stationary problem, Optimistic initial values, Upper Confidence-Bound Action Selection, Gradient Bandits, Associative search.

Finite Markov Decision Process: The Agent-Environment Interface, Goals and Rewards, Unified Notation for Episodic and Continuing Tasks, Policies and Value Functions.

UNIT–II: Dynamic Programming and Temporal-Difference Learning

Dynamic Programming: Policy Evaluation, Policy Improvement, Policy Iteration, Value Iteration, Asynchronous dynamic programming, Generalized Policy Iteration, Efficiency of dynamic programming.

Monte Carlo Methods: Monte Carlo Prediction, Monte Carlo Estimation of Action values, Monte Carlo Control, Monte Carlo Control without Exploring Starts, Off-policy prediction via Importance Sampling.

Temporal-Difference Learning: TD Prediction, Advantages of TD Prediction Methods, Optimality of TD (0), Sarsa: On-policy TD control, Q-learning: Off-policy TD control.

UNIT–III: Planning and Learning with Approximation Methods

Planning and Learning with Tabular Methods: Models and Planning, Integrated Planning, acting and learning, Prioritized Sweeping, Full vs Sample Backups, Trajectory sampling, Heuristic search, Monte carlo tree search.

On-policy Prediction with Approximation: Value-function approximation, stochasticgradient and semi- gradient methods, Linear methods, Feature construction for linear methods, Selecting step-size parameters manually.

UNIT–IV: On-Policy and Off-Policy Control with Approximation

On-policy Control with Approximation: Episodic Semi-Gradient Control, Semi-gradient nstep Sarsa, Average Reward: A New Problem Setting for Continuing Tasks, Deprecating the Discounted Setting, Differential Semigradient n-step Sarsa.

Off-policy Methods with Approximation: Semi-gradient Methods, Examples of Off-policy Divergence, The Deadly Triad, Linear Value-function Geometry, Gradient Descent in the Bellman Error.

UNIT–V: Policy Gradient Methods

Policy Gradient Methods: Policy Approximation and its advantages, The Policy Gradient theorem, Reinforce: Monte Carlo Policy Gradient, Reinforce with Baseline, Actor-Critic methods, Policy gradient for continuing problems, Policy parameterization for continuous actions.

Text Book

1. Reinforcement Learning: An Introduction, R. S. Sutton and A. G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, Cambridge, MA, USA, 2018.

Reference Books

1. An Introduction to Deep Reinforcement Learning, V. François-Lavet, P. Henderson, R. Islam, M. G. Bellemare, and J. Pineau, *An Introduction to Deep Reinforcement Learning*, Now Publishers, Boston, MA, USA, 2018.
2. Algorithms for Reinforcement Learning, C. Szepesvári, *Algorithms for Reinforcement Learning*, Morgan & Claypool Publishers, San Rafael, CA, USA, 2010.
3. Deep Reinforcement Learning Hands-On, M. Lapan, *Deep Reinforcement Learning Hands-On*, 2nd Edition, Packt Publishing, Birmingham, U.K., 2020.
4. Deep Learning, Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, MIT Press, 2016.

M.Tech. (II Sem.) **D252BDB1 - ROBOTICS IN INDUSTRY 4.0**

L	T	P	C
3	0	0	3

PRE-REQUISITES:

Students should have basic knowledge of Robotics, Internet of Things, embedded systems, sensors, automation, and computer networks. Familiarity with industrial automation, control systems, and programming concepts will help students understand Industry 4.0 technologies and intelligent robotic applications effectively.

COURSE EDUCATIONAL OBJECTIVES:

The course is designed to provide students with comprehensive knowledge of Industry 4.0 technologies including robotics, automation, Internet of Things (IoT), Artificial Intelligence (AI), Cyber-Physical Systems (CPS), and smart manufacturing systems. The students will develop the ability to analyze intelligent industrial automation systems, integrate robotics with IoT and cloud technologies, and apply advanced control and communication techniques for smart factory applications. The course also aims to enhance understanding of human–robot interaction, collaborative robotics, industrial safety standards, and ethical considerations in Industry 4.0 environments.

Course Outcomes: At the end of the course, the student will be able

CO1: Apply the fundamental concepts and enabling technologies of Industry 4.0 in intelligent manufacturing systems. **(Applying-L3)**

CO2: Apply the principles of industrial robotics and automation in modern smart manufacturing environments. **(Applying-L3)**

CO3: Analyze automation systems and Cyber-Physical Systems (CPS) used in Industry 4.0 applications. **(Analyzing-L4)**

CO4: Analyze IoT, communication networks, cloud robotics, and AI techniques in robotic and industrial automation applications. **(Analyzing-L4)**

CO5: Evaluate robot–human interaction, safety standards, and ethical considerations in Industry 4.0 environments. **(Evaluating-L5)**

UNIT–I: Introduction to Industry 4.0

Introduction to Industry 4.0: Overview of Industry 4.0: Concept and evolution of Industry 4.0, Key technologies, and their impact on the manufacturing sector. Core components of Industry 4.0-Cyber-physical systems (CPS), Internet of Things (IoT), Big Data Analytics, Cloud computing, Artificial Intelligence (AI) and Machine Learning (ML) in manufacturing, Role of Robotics in Industry 4.0.

UNIT–II: Robotics in Automated Manufacturing Systems

Robotics in Automated Manufacturing Systems: Industrial robots, collaborative robots (Cobots), autonomous mobile robots (AMRs). Smart Factories: Integration of robots in smart factory systems, modular and flexible automation. Collaborative Robotics (Cobots): Design and safety in human-robot collaborative environments. Future Trends in Industry 4.0 and Robotics: Robotics in Industry 5.0, AI-driven manufacturing, and autonomous factories.

UNIT–III: Advanced Control and Automation in Robotics

Advanced Control and Automation in Robotics: Robot Control Systems: Advanced control methods for robots (PID, adaptive control, robust control). Automation Systems: Industrial automation with robotics, PLCs, SCADA systems, and real-time control. Robot Programming in Industry 4.0: Offline programming, simulation tools (e.g., ROS, Robot Studio, VREP). Cyber-Physical Systems: Robotics as part of CPS in Industry 4.0.

UNIT–IV: IoT and Robotics Integration

IoT and Robotics Integration: Role of IoT in smart manufacturing, communication protocols (MQTT, OPC-UA). Cloud Robotics: Cloud-based control, data analytics, and remote diagnostics for robots. AI for Robotics: Machine learning and computer vision techniques for robotic applications in Industry 4.0. Edge Computing for Robotics: Real-time data processing at the edge, minimizing latency in critical applications. Digital Twin Technology: Virtual representation of physical systems, monitoring and control of robotic systems.

UNIT–V: Human–Robot Interaction and Safety

Human-Robot Interaction (HRI) and Safety: Safety Standards in Robotics: ISO 10218, ISO/TS 15066, collaborative robot safety. Human-Robot Interaction: Ergonomics, intuitive interfaces, user feedback systems, multimodal interaction (gestures, voice, vision).

Ethical Considerations in Industry 4.0 Robotics: Safety, privacy concerns, and ethical issues in autonomous systems. Robot Behavior and Learning: Behavior-based design, Learning from Demonstration (LfD), reinforcement learning.

Text Books

1. Automation, Production Systems, and Computer-Integrated Manufacturing, M. P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, Pearson Education, Boston, MA, USA, 2016.
2. Robotics for Engineers, S. B. Niku, *Robotics for Engineers (Mechanical Perspective)*, Wiley Publications, Hoboken, NJ, USA, 2015.

Reference Books

1. Introduction to Robotics: Mechanics and Control, J. J. Craig, *Introduction to Robotics: Mechanics and Control*, 3rd Edition, Pearson Education, Boston, MA, USA, 2005.
2. Industry 4.0 in Production Engineering, T. Bauernhansl, M. ten Hompel, and B. Vogel-Heuser, *Industry 4.0 in Production Engineering*, Springer Vieweg, Berlin, Germany, 2014.
3. KUKA Robotics Manuals
4. ABB RobotStudio Documentation
5. FANUC Robotics Documentation
6. McKinsey Industry 4.0 Insights

M.Tech. (II Sem.) **D252BDB2 - EMBEDDED SYSTEM DESIGN**

L	T	P	C
3	0	0	3

Pre-requisites: Computer Fundamentals

Students should have basic knowledge of Embedded Systems, computer fundamentals, digital electronics, microprocessors, programming concepts, and operating systems. Familiarity with hardware interfacing, C programming, and system architecture will help students understand embedded system modeling, design, and optimization techniques effectively.

Course Educational Objectives (CEOs)

The course is designed to provide students with comprehensive knowledge of embedded system modeling, hardware and software design, application mapping, optimization, and testing techniques. The students will develop the ability to analyze embedded system architectures, evaluate processor performance, and implement rapid prototyping and validation methods. The course also aims to enhance understanding of scheduling, optimization strategies, and embedded application development for real-time and intelligent systems.

Course Outcomes: At the end of the course the student will be able to

CO1: Apply various modeling techniques for embedded system design and development. **(Applying-L3)**

CO2: Analyze the role of hardware and software components in embedded system architecture and design. **(Analyzing-L4)**

CO3: Analyze processor performance evaluation methods and rapid prototyping techniques for embedded systems. **(Analyzing-L4)**

CO4: Evaluate scheduling and application mapping techniques in embedded system design. **(Evaluating-L5)**

CO5: Evaluate optimization and testing techniques for improving embedded system performance and reliability. **(Evaluating-L5)**

UNIT–I: Introduction to Embedded Systems, Specifications, and Modeling

INTRODUCTION TO EMBEDDED SYSTEMS, SPECIFICATIONS, AND MODELING: Opportunities – Challenges - design flows – requirements - models of computation - Early design phases communicating finite state machines - timed automata - data flow - levels of hardware modelling – comparison of models of computation - unified modelling language (UML)

UNIT–II: Embedded System Hardware and Software Design

EMBEDDED SYSTEM HARDWARE AND SOFTWARE DESIGN: Input - processing units – memories – communication – output -mechanical energy - secure hardware, embedded software - embedded operating system, resource access protocols - hardware abstraction layer.

UNIT–III: Processor Evaluation and Validation

PROCESSOR EVALUATION AND VALIDATION: Performance evaluation - quality metrics-energy and power models - dependability and risk analysis – simulation rapid prototyping - formal verification.

UNIT–IV: Application Mapping

APPLICATION MAPPING: Definition of scheduling problems - scheduling for uniprocessors - Scheduling for Independent Jobs on Identical Multiprocessors - Scheduling for Independent Jobs on Identical processors. Applications: Elevators, GSM, GPS, Washing machines.

UNIT–V: Optimization and Testing

OPTIMIZATION AND TESTING: High level optimizations - simple loop transformations - loop tiling/blocking - loop splitting - array folding - floating point to fixed point conversion, test- scope - test procedures - evaluation of test pattern sets - design for testability. Project management.

Text Books

1. Embedded System Design, P. Marwedel, *Embedded System Design*, 3rd Edition, Springer Publications, 2018.
2. Embedded Systems Architecture: A Comprehensive Guide for Engineers and Programmers, T. Noergaard, *Embedded Systems Architecture: A Comprehensive Guide for Engineers and Programmers*, 2nd Edition, Newnes Publications, 2013.
3. Making Embedded Systems, E. White, *Making Embedded Systems*, O'Reilly Series, SPD Publications, 2011.

Reference Books

1. Behaviour-Based Robotics, R. C. Arkin, *Behaviour-Based Robotics*, MIT Press, 1998.
2. Embedded Systems – An Integrated Approach, L. B. Das, *Embedded Systems – An Integrated Approach*, Pearson Education, 2013.
3. Embedded Systems Design, Steve Heath, *Embedded Systems Design*, 2nd Edition, Newnes Publications, 2003.
4. Real-Time Embedded Systems, Xiaocong Fan, *Real-Time Embedded Systems: Design Principles and Engineering Practices*, Elsevier Publications, 2015.

M.Tech. (II Sem.) D252BDB3 - ADVANCED OPERATIONS RESEARCH

L	T	P	C
3	0	0	3

Prerequisites:

Students should have basic knowledge of Engineering Mathematics, probability and statistics, linear algebra, and calculus. Familiarity with mathematical modeling, matrices, and optimization concepts will help students understand advanced operations research techniques and decision-making models effectively.

Course Educational Objectives (CEOs)

The course is designed to provide students with comprehensive knowledge of optimization techniques, mathematical modeling, inventory control, nonlinear programming, and decision-making methods used in engineering and industrial systems. The students will develop the ability to formulate and solve linear and nonlinear optimization problems, analyze inventory and queuing systems, and apply dynamic programming and network models for industrial applications. The course also aims to enhance analytical and problem-solving skills for effective resource allocation, scheduling, and operational decision-making.

Course Outcomes: At the end of the course, the student will be able

CO1: Formulate and solve linear programming problems using simplex and related optimization techniques. **(Applying-L3)**

CO2: Analyze sensitivity and parametric changes in optimization problems for decision-making applications. **(Analyzing-L4)**

CO3: Apply nonlinear programming techniques for solving optimization problems with nonlinear objectives and constraints. **(Applying-L3)**

CO4: Analyze deterministic and probabilistic inventory control models for industrial applications. **(Analyzing-L4)**

CO5: Apply dynamic programming, network models, and game theory techniques for solving complex operational problems. **(Applying-L3)**

UNIT–I: Linear Programming and Optimization Modeling

Introduction to operations research and optimization techniques. Mathematical model formulation for engineering systems. Linear programming problems (LPP), assumptions, and applications. Graphical solution methods for LPP. Simplex method and revised simplex method. Degeneracy, alternate optimal solutions, infeasible and unbounded solutions. Applications in engineering optimization and industrial decision-making.

UNIT–II: Duality and Sensitivity Analysis

Duality theory and economic interpretation of dual variables. Dual simplex method. Sensitivity analysis and post-optimality analysis. Parametric programming techniques. Transportation and assignment models. Integer programming concepts and applications in engineering systems.

UNIT–III: Nonlinear Programming and Project Management

Nonlinear programming problems and classification. Constrained optimization techniques. Kuhn–Tucker optimality conditions. Convex programming concepts. Quadratic programming and geometric programming methods.

Project scheduling and management techniques – Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), project crashing, and resource allocation methods.

UNIT–IV: Inventory and Queuing Models

Deterministic inventory control models – EOQ models, production inventory models, quantity discount models, and selective inventory control techniques. Probabilistic inventory models for uncertain demand systems.

Queueing theory – characteristics of queueing systems, single-server and multi-server models, Poisson arrival and exponential service systems, queue performance measures, and applications in industrial and service systems.

UNIT–V: Dynamic Programming, Network Models, and Simulation

Dynamic programming concepts and applications in discrete and continuous optimization problems. Network models – shortest path problems, minimum spanning tree, maximum flow models, and transportation networks.

Game theory – two-person zero-sum games, pure and mixed strategies. Simulation techniques – Monte Carlo simulation, random number generation, and applications in industrial and robotic systems.

TEXT BOOKS:

1. Operations Research, Kanthi Swarup, P. K. Gupta, and Man Mohan, *Operations Research*, 14th Edition, Sultan Chand & Sons, New Delhi, India, 2008.
2. Operations Research, S. D. Sharma, *Operations Research*, Kedar Nath Ram Nath Publishers, Meerut, India, 2008.

REFERENCE BOOKS

1. Operations Research: An Introduction, H. A. Taha, *Operations Research: An Introduction*, 10th Edition, Pearson Education, 2017.
2. Introduction to Operations Research, F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, 10th Edition, McGraw-Hill Education, 2015.
3. Operations Research: Theory and Applications, J. K. Sharma, *Operations Research: Theory and Applications*, 6th Edition, Macmillan Publishers India Ltd., 2017.
4. Operations Research, Pannerselvam, *Operations Research*, 3rd Edition, PHI Learning Pvt. Ltd., 2016.
5. Introduction to Optimization: Operations Research, J. C. Pant, *Introduction to Optimization: Operations Research*, Jain Brothers, New Delhi, India, 2008.

M.Tech. (III Sem.) D2530001/M- RESEARCH METHODOLOGY AND IPR

L	T	P	C
3	0	0	3

Pre-requisites:
No specific prerequisites are required. However, basic knowledge of Research Methodology, engineering fundamentals, technical communication, and computer applications will help students understand research processes, technical documentation, and Intellectual Property Rights (IPR) effectively.

COURSE OBJECTIVES (CEOs):
The course is designed to provide students with comprehensive knowledge of research methodology, technical writing, ethics in research, and Intellectual Property Rights (IPR). The students will develop the ability to identify research problems, conduct literature surveys, prepare technical reports and research proposals, and apply ethical practices in engineering research. The course also aims to familiarize students with patent laws, copyright systems, technology transfer, and recent developments in IPR for innovation-driven research and product development.

COURSE OUTCOMES(COs): At the end of the course, the student will be able to

CO1: Analyze engineering research problems and develop appropriate research methodologies for scientific investigations. **(Analyzing-L4)**
CO2: Apply literature review techniques, technical writing skills, and research ethics for preparing research reports and proposals. **(Applying-L3)**
CO3: Apply the fundamentals of patent laws, patent drafting, and intellectual property protection in engineering research. **(Applying-L3)**
CO4: Analyze copyright laws, industrial designs, licensing, and technology transfer mechanisms in Intellectual Property Rights systems. **(Analyzing-L4)**
CO5: Evaluate recent developments in Intellectual Property Rights and apply software tools and databases for patent filing and research management**. (Evaluating-L5)**

UNIT–I: Introduction to Research Methodology
Meaning and objectives of research. Types and characteristics of research problems. Sources of research problems. Criteria and characteristics of good research problems. Errors in selecting research problems. Scope and objectives of research work.
Research approaches and investigation methods. Data collection techniques, analysis, interpretation, and required instrumentation for engineering research.

UNIT–II: Literature Review and Research Ethics
Effective literature survey techniques and technical reading approaches. Research paper analysis and referencing methods. Plagiarism and plagiarism detection tools. Research ethics and ethical practices in engineering research.
Technical writing skills – report writing, paper writing, thesis preparation, and technical presentations. Development of research proposals, proposal format, review process, and assessment by review committees.

UNIT–III: Intellectual Property Rights and Patenting
Nature and importance of Intellectual Property Rights (IPR). Patents, copyrights, trademarks, industrial designs, and trade secrets. Innovation and technology development process.
Patent drafting and patent filing procedures. International cooperation in intellectual property systems. Patent Cooperation Treaty (PCT) and international patenting procedures.

UNIT–IV: Patent Rights and Technology Transfer

Scope and significance of patent rights. Licensing and transfer of technology. Patent information systems and patent databases. Geographical indications and their applications.

Case studies related to patents, innovation management, and intellectual property protection in engineering systems.

UNIT–V: Recent Developments in IPR

Administration and management of patent systems. Emerging trends and recent developments in Intellectual Property Rights. IPR in biological systems, computer software, and digital technologies. Traditional knowledge systems and IPR protection. Applications of software tools for patent filing, documentation, and intellectual property management. Case studies in engineering and technology domains.

TEXT BOOKS:

1. Research Methodology: Methods and Techniques, C. R. Kothari and Gaurav Garg, *Research Methodology: Methods and Techniques*, 4th Edition, New Age International Publishers, 2019.
2. Research Methodology: A Step-by-Step Guide for Beginners, Ranjit Kumar, *Research Methodology: A Step-by-Step Guide for Beginners*, 5th Edition, SAGE Publications, 2019.

REFERENCE BOOKS:

1. Research Methodology: An Introduction for Science and Engineering Students, Stuart Melville and Wayne Goddard, *Research Methodology: An Introduction for Science and Engineering Students*, Juta Academic Publishers, 2004.
2. Research Methodology: An Introduction, Wayne Goddard and Stuart Melville, *Research Methodology: An Introduction*, Juta Academic Publishers, 2004.
3. Resisting Intellectual Property, Debora J. Halbert, *Resisting Intellectual Property*, Taylor & Francis Ltd., 2007.
4. Industrial Design, W. H. Mayall, *Industrial Design*, McGraw-Hill Publications, 1992.
5. Product Design, Benjamin W. Niebel, *Product Design*, McGraw-Hill Publications, 1974.
6. Introduction to Design, Morris Asimow, *Introduction to Design*, Prentice Hall, 1962.
7. Intellectual Property in the New Technological Age, Robert P. Merges, Peter S. Menell, and Mark A. Lemley, *Intellectual Property in the New Technological Age*, 2016.
8. Intellectual Property Rights Under WTO, T. Ramappa, *Intellectual Property Rights Under WTO*, S. Chand Publications, 2008.

WEB REFERENCES:

Please include hyperlinks related to NPTEL/VLabs etc.

1. NPTEL – Research Methodology Course
2. Google Patents
3. Virtual Labs – IIT Kharagpur
4. World Intellectual Property Organization (WIPO)
5. Indian Patent Advanced Search System (InPASS)

M.Tech. (III Sem.)	D253000S- SUMMER INTERNSHIP/INDUSTRIAL TRAINING	L	T	P	C
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Pre-requisites:

Students should have completed the core courses offered during the first and second semesters of the M.Tech. program. Basic knowledge of Robotics, automation, manufacturing systems, embedded systems, control systems, and engineering analysis techniques will help students effectively carry out industrial training and technical assignments in industry or research organizations.

Course Educational Objectives (CEOs)

The course is designed to provide students with practical exposure to industrial practices, professional work environments, and real-world engineering applications through internship or industrial training in relevant industries, research laboratories, or organizations. The students will develop the ability to apply theoretical concepts to practical engineering problems, analyze industrial processes and systems, and gain hands-on experience in technical problem-solving. The course also aims to enhance professional communication, teamwork, project management, technical documentation, and lifelong learning skills required for research and industrial careers.

COURSE EDUCATIONAL OBJECTIVES(CEOs): To make the students undergo internship training in a core industry independently and submit a report.

COURSE OUTCOMES(COs): After the completion of the course, students should be able to

CO1: Apply engineering concepts and technical knowledge to solve industrial or research-oriented problems during internship training. **(Applying-L3)**

CO2: Analyze the working principles, operational mechanisms, and processes of industrial systems and manufacturing plants. **(Analyzing-L4)**

CO3: Interpret and evaluate technical data, industrial practices, and process observations independently. **(Evaluating-L5)**

CO4: Prepare and present a well-structured technical report based on internship or industrial training activities. **(Applying-L3)**

CO5: Demonstrate professional ethics, teamwork, communication skills, and project management practices in industrial environments. **(Applying-L3)**

COURSE CONTENTS

The student shall undergo industrial internship/training in a relevant industry, research organization, startup, manufacturing unit, automation company, robotics laboratory, or government/private technical organization for a specified duration as prescribed by the institute/university.

The internship/training shall include:

- Exposure to industrial practices and work culture
- Study of industrial processes, systems, and technologies
- Participation in technical activities, maintenance, testing, design, development, or automation tasks
- Data collection, technical analysis, and problem-solving activities
- Interaction with industry professionals and technical experts
- Preparation of internship diary and technical report

Internship Report and Evaluation

The student shall submit:

- Internship completion certificate from the organization
- Internship diary/logbook
- Detailed technical report highlighting objectives, methodology, observations, analysis, and outcomes
- Presentation and viva-voce examination

Evaluation shall be based on:

- Performance during internship/training
- Quality of technical work carried out
- Technical report preparation
- Presentation and viva-voce performance
- Feedback from industry/research supervisor

Suggested Areas for Internship / Industrial Training

- Industrial Robotics and Automation
- Embedded Systems and IoT
- Machine Vision and AI Applications
- PLC and SCADA Systems
- Smart Manufacturing and Industry 4.0
- Mobile Robotics and Autonomous Systems
- CAD/CAM and Digital Manufacturing
- Machine Learning and Reinforcement Learning
- Mechatronics and Control Systems
- Research and Development Laboratories

References

1. Engineering Ethics, Charles E. Harris Jr., Michael S. Pritchard, and Michael J. Rabins, *Engineering Ethics: Concepts and Cases*, Cengage Learning.
2. Technical Communication, Meenakshi Raman and Sangeeta Sharma, *Technical Communication: Principles and Practice*, Oxford University Press.
3. Project Management for Engineering and Technology, John M. Nicholas and Herman Steyn, *Project Management for Engineering, Business and Technology*, Routledge Publications.

L	T	P	C
0	0	0	2

M.Tech. (III Sem.) **D25300CV- COMPREHENSIVE VIVA**

Pre-requisites:
Students should have successfully completed the core and elective courses offered during the first and second semesters of the M.Tech. program. Adequate knowledge of Robotics, automation, embedded systems, control systems, artificial intelligence, and research methodology will help students effectively participate in technical discussions and viva-voce examinations.

COURSE EDUCATIONAL OBJECTIVES(CEOs):

The course is designed to assess the comprehensive understanding of students in the subjects studied during the first and second semesters of the M.Tech. program. The students will develop the ability to integrate theoretical concepts with practical engineering applications, analyze technical problems independently, and communicate technical ideas effectively. The course also aims to enhance confidence, professional communication skills, technical presentation abilities, and preparedness for research, higher studies, and industrial interviews.

COURSE OUTCOMES(COs): After the completion of the course, students should be able to

CO1: Demonstrate confidence and technical competence in answering subject-related questions during interviews and viva-voce examinations. **(Applying-L3)**
CO2: Analyze and integrate theoretical concepts from various courses studied in the M.Tech. program. **(Analyzing-L4)**
CO3: Evaluate and interpret technical data, engineering problems, and research-oriented concepts independently. **(Evaluating-L5)**
CO4: Demonstrate professional communication, presentation, and interpersonal skills in technical discussions. **(Applying-L3)**
CO5: Apply multidisciplinary knowledge and problem-solving skills to address advanced engineering and research challenges. **(Applying-L3)**

COURSE CONTENTS
The comprehensive viva-voce examination shall cover the theoretical, analytical, practical, and research-oriented concepts studied during the first and second semesters of the M.Tech. program.
The evaluation may include:

- Fundamentals of core and elective subjects
- Robotics and automation concepts
- Embedded systems and intelligent control systems
- Artificial intelligence and machine learning applications
- Industrial automation and Industry 4.0 technologies
- Research methodology and technical communication
- Problem-solving and analytical aptitude
- Technical presentation and communication skills
- Recent advancements and emerging technologies related to the specialization

Evaluation Methodology
The comprehensive viva-voce examination shall be conducted by an internal and/or external examination committee. Evaluation shall be based on:

- Subject knowledge and conceptual understanding
- Analytical and problem-solving ability

- Technical communication and presentation skills
- Confidence and clarity in technical discussions
- Ability to relate theory with practical and industrial applications
- Interdisciplinary knowledge and research orientation

Suggested Areas for Preparation

- Robotics and Industrial Automation
- Embedded Systems and IoT
- Machine Vision and Artificial Intelligence
- Mobile Robotics and Reinforcement Learning
- Sensors, Actuators, and Control Systems
- Industry 4.0 and Smart Manufacturing
- Research Methodology and Technical Writing
- Optimization and Operations Research

References

1. Technical Communication, Meenakshi Raman and Sangeeta Sharma, *Technical Communication: Principles and Practice*, Oxford University Press.
2. Engineering Ethics, Charles E. Harris Jr., Michael S. Pritchard, and Michael J. Rabins, *Engineering Ethics: Concepts and Cases*, Cengage Learning.
3. The Unwritten Laws of Engineering, W. J. King, *The Unwritten Laws of Engineering*, ASME Press.

L	T	P	C
0	0	20	10

M.Tech. (III Sem.) **D253000P- DISSERTATION PART– A**

Pre-requisites :

Students should have successfully completed the core and elective courses offered during the first and second semesters of the M.Tech. program. Adequate knowledge of Research Methodology, robotics, automation, control systems, artificial intelligence, embedded systems, and engineering analysis techniques will help students effectively carry out research-oriented dissertation work.

COURSE EDUCATIONAL OBJECTIVE (CEO):

The course is designed to provide students with research-oriented training for identifying, planning, and executing an independent dissertation project in advanced areas related to robotics, automation, intelligent systems, and allied engineering domains. The students will develop the ability to perform literature surveys, identify research gaps, formulate objectives, and design suitable methodologies for solving engineering and research problems. The course also aims to enhance analytical thinking, technical writing, experimentation, simulation, modeling, and research communication skills required for higher studies, industrial R&D, and academic research.

COURSE OUTCOMES (COs): After the completion of the course, students should be able

CO1: Identify and formulate a research problem in advanced areas of robotics, automation, intelligent systems, or related engineering domains. **(Analyzing-L4)**

CO2: Analyze research literature to identify research gaps and define objectives and scope of the dissertation work. **(Analyzing-L4)**

CO3: Develop suitable research methodologies, analytical models, simulation approaches, or experimental procedures based on literature review. **(Creating-L6)**

CO4: Design and develop models, experimental setups, algorithms, simulation frameworks, or computational techniques to achieve the research objectives. **(Creating-L6)**

CO5: Demonstrate technical documentation, presentation, and research communication skills through dissertation reports and seminars. **(Applying-L3)**

COURSE CONTENTS

The dissertation work shall involve independent study, research, design, experimentation, simulation, modeling, implementation, and analysis related to a selected research problem in the area of specialization.

The activities may include:

- Identification of research problem and topic selection
- Comprehensive literature review and gap analysis
- Formulation of objectives and scope of work
- Development of mathematical models, algorithms, or simulation frameworks
- Design and fabrication of experimental setup, if applicable
- Data collection, experimentation, and analysis
- Validation of results and performance evaluation
- Preparation of dissertation synopsis and technical presentations
- Seminar presentations and periodic progress reviews

Evaluation Methodology

The evaluation shall be based on:

- Problem identification and relevance of research topic
- Literature review and research gap identification
- Quality of research methodology and technical approach
- Progress in modeling, simulation, experimentation, or implementation
- Technical presentation and seminar performance
- Dissertation report preparation and documentation
- Innovation, originality, and research contribution

Suggested Areas for Dissertation Work

- Robotics and Intelligent Systems
- Industrial Automation and Industry 4.0
- Machine Vision and Artificial Intelligence
- Reinforcement Learning and Autonomous Systems
- Embedded Systems and IoT
- Mobile and Micro Robotics
- Human–Robot Interaction
- Smart Manufacturing and Digital Twin Systems
- Control Systems and Mechatronics
- Sensors, Actuators, and Autonomous Navigation

References

1. Research Methodology: Methods and Techniques, C. R. Kothari and Gaurav Garg, *Research Methodology: Methods and Techniques*, New Age International Publishers.
2. Research Methodology: A Step-by-Step Guide for Beginners, Ranjit Kumar, *Research Methodology: A Step-by-Step Guide for Beginners*, SAGE Publications.
3. The Craft of Research, Wayne C. Booth, Gregory G. Colomb, and Joseph M. Williams, *The Craft of Research*, University of Chicago Press.

L	T	P	C
0	0	32	16

M.Tech. (IV Sem.) **D254000P- DISSERTATION PART– B**

Pre-requisites :
Students should have successfully completed the core and elective courses offered during the first and second semesters of the M.Tech. program and should have completed Research Methodology and Dissertation Part–A. Adequate knowledge of robotics, automation, intelligent systems, experimental methods, simulation tools, and technical documentation is essential for carrying out independent research and dissertation work.

COURSE EDUCATIONAL OBJECTIVE (CEO):

The course is designed to provide students with advanced research experience through the execution, implementation, validation, and completion of a dissertation project in specialized areas of robotics, automation, intelligent systems, and allied engineering domains. The students will develop the ability to conduct independent research, perform experimentation and simulations, analyze technical results, and derive meaningful conclusions. The course also aims to enhance technical writing, publication, presentation, innovation, ethical research practices, and professional competence required for academic research, industrial R&D, and higher-level engineering careers.

COURSEOUTCOMES(COs): After the completion of the course, students should be able to
CO1: Develop and implement appropriate methodologies, experimental procedures, algorithms, software codes, or computational techniques for dissertation work. **(Creating-L6)**
CO2: Evaluate engineering solutions and research methodologies considering societal, environmental, sustainability, and ethical aspects. **(L5 – Evaluate)**
CO3: Analyze experimental, simulation, or computational results and draw valid technical conclusions. **(Analyzing-L4)**
CO4: Prepare and defend a dissertation report in the prescribed technical format through seminars and viva-voce examinations. **(Applying-L3)**
CO5: Develop research publications and explore opportunities for presenting or publishing research work in peer-reviewed journals and conferences. **(Creating-L6)**

COURSE CONTENTS
The dissertation work shall involve advanced independent research, implementation, experimentation, analysis, validation, and documentation related to the selected research problem initiated during Dissertation Part–A.
The activities may include:

- Finalization of research objectives and methodology
- Design and development of algorithms, models, or experimental systems
- Simulation, coding, fabrication, and implementation of research work
- Data acquisition, experimentation, and performance evaluation
- Validation and interpretation of experimental/simulation results
- Optimization and comparative analysis of results
- Preparation of technical papers and research publications
- Dissertation writing in standard thesis format
- Seminar presentations, progress reviews, and viva-voce examinations

Evaluation Methodology

The evaluation shall be based on:

- Research contribution and originality of work
- Quality of implementation, experimentation, or simulation
- Analytical ability and interpretation of results
- Technical quality of dissertation report
- Presentation, seminar, and viva-voce performance
- Research publications/paper submissions, if any
- Professional ethics and research methodology adopted

Suggested Areas for Dissertation Work

- Robotics and Autonomous Systems
- Artificial Intelligence and Machine Learning
- Reinforcement Learning for Robotics
- Industrial Automation and Industry 4.0
- Machine Vision and Intelligent Systems
- Embedded Systems and IoT
- Human–Robot Interaction
- Smart Manufacturing and Digital Twin Systems
- Mobile Robotics and Autonomous Navigation
- Control Systems and Intelligent Automation
- Medical Robotics and Assistive Technologies

Dissertation Submission Requirements

The student shall submit:

- Dissertation thesis/report in prescribed university format
- Plagiarism verification report as per institutional norms
- Research publication/paper submission proof (if applicable)
- Seminar and presentation records
- Soft copy and hard copy of dissertation report

Degree Completion Requirement

Successful completion and defense of Dissertation Part–B, along with fulfillment of all academic requirements prescribed by the university/institute, shall lead to the award of the Master of Technology degree in the respective specialization.

References

1. Research Methodology: Methods and Techniques, C. R. Kothari and Gaurav Garg, *Research Methodology: Methods and Techniques*, New Age International Publishers.
2. Research Methodology: A Step-by-Step Guide for Beginners, Ranjit Kumar, *Research Methodology: A Step-by-Step Guide for Beginners*, SAGE Publications.
3. The Craft of Research, Wayne C. Booth, Gregory G. Colomb, and Joseph M. Williams, *The Craft of Research*, University of Chicago Press.
4. Writing for Peer Reviewed Journals, Pat Thomson and Barbara Kamler, *Writing for Peer Reviewed Journals: Strategies for Getting Published*, Routledge Publications.