



DEPARTMENT OF MECHANICAL ENGINEERING

***Scheme of Instruction
and
Syllabus of***

**M.E. (MECHANICAL ENGG)
AUTOMATION & ROBOTICS**

Full Time & CEEP

AICTE Model Curriculum

2026-27



**UNIVERSITY COLLEGE OF ENGINEERING
(Autonomous)**

**Osmania University
Hyderabad – 500 007, TS, INDIA**



UNIVERSITY COLLEGE OF ENGINEERING, OSMANIA UNIVERSITY

VISION OF THE INSTITUTE

The Vision of the Institute is to generate and disseminate knowledge through a harmonious blending of Science, Engineering and Technology. To serve the society by developing a modern technology in students' heightened intellectual, cultural, ethical and humane sensitivities, fostering a scientific temper and promoting professional and technological expertise.

MISSION OF THE INSTITUTE

- To achieve excellence in Teaching and Research.
- To generate, disseminate and preserve knowledge.
- To enable empowerment through knowledge and information.
- Advancement of knowledge in Engineering, Science and Technology.
- Promote learning in free thinking and innovative environment.
- Cultivate skills, attitudes to promote knowledge creation.
- Rendering socially relevant technical services for the community.
- To impart new skills of technology development.
- To inculcate entrepreneurial talents and technology appreciation programmes.
- Technology transfer and incubation.

DEPARTMENT OF MECHANICAL ENGINEERING

VISION OF THE DEPARTMENT

To generate and disseminate knowledge in Mechanical Engineering and nurture professional, technical and scientific temper for serving the needs of the industry, research organizations and society.

MISSION OF THE DEPARTMENT

- Create technically competent mechanical engineers to suit the changing needs of global industry and society.
- To cultivate skills, attitudes to promote knowledge creation and technology development.
- Interact with prominent educational institutions and R&D organizations for enhancing teaching, research and consultancy services.

DEPARTMENT OF MECHANICAL ENGINEERING
M.E (Automation & Robotics)
PROGRAM EDUCATIONAL OBJECTIVES

PEO-1	To provide the requisite fundamentals of varied subjects related to Automation and Robotics field to conceive, plan, model, design, construct, maintain and improve systems to enhance human comfort.
PEO-2	To provide knowledge of experimental, computational, analytical, simulation tools and techniques require to address the challenges in Robotics, Automation and allied engineering fields.
PEO-3	To provide knowledge to apply Robotics and Automation principles to design and implement cost effective systems in medium and low volume manufacturing.
PEO-4	To provide effective communication skills, creative methods, ethics and continuous learning techniques to fulfill their professional requirements and societal needs.

PROGRAM OUTCOMES

At the end of the programme the student shall be able to:

PO-1	Ability to independently carry out research/ investigation and development work to solve practical problems
PO-2	Ability to write and present a substantial technical report/document
PO-3	Students should be able to demonstrate a degree of mastery in Automation & Robotics
PO-4	Use various simulation tools for Analysis and Design of Automation and Robotic systems
PO-5	Function as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.

AICTE-Model Scheme
Scheme of Instructions & Examination
M.E. (Mechanical Engineering-Automation & Robotics) 4 Semesters (Full Time)

S.No .	Subject	Scheme of Studies per Week		Max.Marks		Credits
		L	P	CIE	SEE	
Semester-I						
1.	Core I	3	-	40	60	3
2.	Core II	3	-	40	60	3
3.	Core III	3	-	40	60	3
4.	Program Elective I	3	-	40	60	3
5.	Program Elective II	3	-	40	60	3
6.	Program Elective III	3	-	40	60	3
7.	Laboratory I	0	2	50	--	1
8.	Seminar	0	2	50	--	1
	Total	18	4	340	360	20
Semester-II						
1.	Core IV	3	-	40	60	3
2.	Core V	3	-	40	60	3
3.	Core VI	3	-	40	60	3
4.	Program Elective IV	3	-	40	60	3
5.	Program Elective V	3	-	40	60	3
6.	Open Elective	3	-	40	60	3
7.	Laboratory II	-	2	50	--	1
8.	Laboratory III	-	2	50	--	1
9.	*Mini Project	-	4	50	--	2
	Total	18	8	390	360	22
Semester-III						
1.	Audit Course I	2	-	40	60	0
2.	Audit Course II	2	-	40	60	0
3.	Dissertation Phase I	-	20	100	--	10
	Total	4	20	180	120	10
Semester-IV						
1.	Dissertation Phase II	0	32	100	100	16
	Grand Total	40	68	1010	940	68

Note:

- i. Dissertation-II has two parts, CIE - I and CIE – II, at the end of 8th week and 16th week respectively for evaluation of 50 marks each.
- ii. Audit Courses will be offered in ONLINE mode and SEE will be conducted in Computer Based Test Mode.
- iii. Research Methodology and IPR will be offered as an Audit Course for all PG Programs.
- iv. Engineering Research Methodology Workshop will be conducted for one week for Ph.D scholars.

*If the student is selected for Industry Internship, then he/she has to complete the required courses of Program elective V and Open Elective through **SWAYAM-NPTEL MOOCS** Courses for getting the required credits. However the students are required to consult Head & CBoS (Autonomous) for due approval, before he/ she registers for the course in SWAYAM-NPTEL portal.*

AICTE-Model Scheme

Scheme of Instructions & Examination

M.E.(Mechanical Engineering- Automation & Robotics) 6 Semesters (Part Time)

S.No.	Subject	Contact hours per Week		Scheme of Examination		Credits
		L	P	CIE	SEE	
Semester-I						
1.	Core -I	3	-	40	60	3
2.	Core V/ Program Elective -II	3	-	40	60	3
3.	Program Elective -I	3	-	40	60	3
4.	Laboratory-I	-	2	50	--	1
	Total	9	2	170	180	10
Semester-II						
1.	Core-II	3	-	40	60	3
2.	Core V/Program Elective-II	3	-	40	60	3
3.	Program Elective-III	3	-	40	60	3
4.	Seminar	-	2	50	--	1
	Total	9	2	170	180	10
Semester-III						
1.	Core-III	3	-	40	60	3
2.	Core-VI/ Program Elective-IV	3	-	40	60	3
3.	Program Elective-V	3	-	40	60	3
4.	Laboratory-II	-	2	50	--	1
	Total	9	2	170	180	10
Semester-IV						
1.	Core-IV	3	-	40	60	3
2.	Core-VI/ Program Elective-IV	3	-	40	60	3
3.	Open Elective	3	-	40	60	3
4.	Mini Project	-	4	50	--	2
5.	Laboratory-III	-	2	50	--	1
	Total	9	6	220	180	12
Semester-V						
1.	Audit Course I	2	-	40	60	0
2.	Audit Course II	2	-	40	60	0
3.	Dissertation Phase I	-	20	100	--	10
	Total	4	20	180	120	10
Semester-VI						
1.	Dissertation Phase II	0	32	100	100	16
	Grand Total	40	68	1010	940	68

M.E. (Mechanical Engineering) Specialization: **Automation & Robotics**

M.E. (Mechanical Engineering) Specialization: **Automation & Robotics**

Type of course	Course Code	Course Name	Contact hours per week			Scheme of Examination		Credits
			L	T	P	CIE	SEE	
SEMESTER-I								
Core-I	ME301	Advanced Robotics	3			40	60	3
Core-II	ME302	Drives & Motion Control for Automation	3			40	60	3
Core-III	ME303	Embedded Systems and Edge Computing for Robotics	3			40	60	3
Program Elective -I	ME311	Finite Element Techniques	3			40	60	3
	ME312	Robot Perception and Computer Vision						
	ME313	Industry 4.0 and Smart Manufacturing						
	ME314	Virtual Reality, Augmented Reality and Digital Twin Systems						
	ME315	Python Programming for Robotics						
	ME316	Mechatronics						
Program Elective -II	ME317	Wearable Robotics and Exoskeleton Systems	3			40	60	3
	ME318	Planar multibody dynamics and simulation						
	ME319	UAV Design, Flight Dynamics and Autonomous Aerial Systems						
	ME320	Industrial Automation and PLC Systems						
	ME321	Evolutionary Computation for Robotics and Autonomous Systems						
Program Elective -III	ME322	Smart Materials and Soft Robotics	3			40	60	3
	ME323	Intelligent Mobile Robots and Autonomous Systems						
	ME324	Reinforcement Learning for Robotics and Autonomous Systems						
	ME325	Human-Robot Interaction and Collaborative Robotics						
	ME326	Vibration Analysis, Condition Monitoring and Predictive Maintenance						
Lab-I	ME351	ROS2 and Intelligent Robotics Laboratory			2	50	-	1
Seminar	ME361	Seminar			2	50	-	1
TOTAL			18	0	4	340	360	20
SEMESTER-II								
Core-IV	ME304	Dynamic Locomotion and Legged Robotics	3			40	60	3
Core-V	ME305	Motion Planning and Autonomous Navigation	3			40	60	3
Core-VI	ME306	Modern Control systems	3			40	60	3
Program Elective -IV	ME327	Signal Processing for Robotics and Autonomous Systems	3			40	60	3
	ME328	Robotic Manipulation, Grasping and Force Control						
	ME329	Intelligent Fluid Power Systems						
	ME330	Multi-Robot Systems and Swarm Robotics						
	ME106	Additive Manufacturing Technologies and Applications						
Program Elective -V	ME331	Machine Learning for Mechanical Systems	3			40	60	3
	ME332	Bio-Inspired Robotics and Intelligent Systems						
	ME333	Agentic AI for Robotics						
	ME334	Multi-Sensor Fusion and State Estimation						
	ME335	Digital Twin Engineering for Robotics and						

With effect from academic year 2026-27

		Smart Systems						
Open Elective	OE941BM	Medical Assistive Devices	3			40	60	3
	OE942BM	Medical Imaging Techniques						
	OE941CE	Green Building Technology						
	OE942CE	Cost Management of Engineering Projects						
	OE941CS	Business Analytics						
	OE941EC	Elements of Embedded Systems						
	OE941EE	Waste to Energy						
	OE942EE	Power Plant Control and Instrumentation						
	OE941ME	Operations Research						
	OE942ME	Advanced Materials						
	OE943ME	Industrial Safety						
	OE941LA	Intellectual Property Rights						
Lab-II	ME352	Robotic Drives and Control Systems Laboratory	-	-	2	50	-	1
Lab-III	ME353	Robotics Simulation and Computational Laboratory	-	-	2	50	-	1
Core	MC070	Mini Project			4	50	-	2
TOTAL			18	-	8	390	360	22
SEMESTER-III								
Audit-I (Online)	AC 030 ME	Research Methodology in Mechanical Engineering	2			40	60	0
Audit-II (Online)	AC 031	English for Research Paper Writing	2			40	60	0
	AC 032	Disaster Mitigation & Management						
	AC 033	Sanskrit for Technical Knowledge						
	AC 034	Value Education						
	AC 035	Stress Management by Yoga						
	AC 036	Personality Development Through Life Enlightenment Skills						
	AC 037	Constitution of India						
	AC 038	Pedagogy Studies						
	AC 039	E-Waste Management						
	ME381	Dissertation Phase -I	-	-	20	100	--	10
TOTAL			04	-	20	180	120	10
SEMESTER-IV								
	ME382	Dissertation Phase -II	-	-	32	100	100	16
GRAND TOTAL			40	-	68	1010	940	68

SEMESTER-I

Course Code ME 301	ADVANCED ROBOTICS						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand robot architectures, kinematics, dynamics, and control principles.
- Develop mathematical models of robotic manipulators using classical and modern formulations.
- Analyze robot motion, constrained multibody systems, and trajectory planning techniques.
- Design robot motion and force control algorithms for industrial and autonomous robotic systems
- Apply advanced robotic concepts to industrial, collaborative, service, and intelligent robots.

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

1. Model robotic systems using kinematic formulations based on Denavit–Hartenberg parameters and Product of Exponentials (PoE).
2. Analyze forward and inverse kinematics, differential kinematics, and singularities of robotic manipulators.
3. Formulate robot dynamics using Newton–Euler and Euler–Lagrange methods and analyze constrained multibody robotic systems.
4. Design trajectory planning and robot control algorithms for motion and force control.
5. Analyze robot manipulation, collaborative robotics, and emerging intelligent robotic applications.

UNIT – I Robot Fundamentals and Components

History and evolution of robots; classifications and configurations of robots; robot subsystems; degrees of freedom; workspace analysis; resolution, repeatability and accuracy; mechanisms and transmission systems; end effectors and grippers; vacuum and special gripping devices; pneumatic, hydraulic and electrical actuators; robot sensors (encoders, force/torque sensors, vision sensors, IMUs); robot controllers; robot programming concepts; industrial robot specifications; applications of industrial, collaborative, service and autonomous robots; case studies of ABB and KUKA robots.

UNIT – II Robot Kinematics

Rotation matrices; Euler angle representation; Roll–Pitch–Yaw (RPY) representation; homogeneous transformation matrices; Denavit–Hartenberg (DH) notation; forward kinematics; representation of position and orientation; inverse kinematics; inverse orientation and inverse position problems; kinematic modelling of serial manipulators; case studies of SCARA, PUMA and six-degree-of-freedom industrial manipulators.

UNIT – III Jacobean, Screw theory and Trajectory Planning

Differential kinematics; velocity analysis; Jacobian matrix; singularities and manipulability; Screw Theory: rigid body motion, twists and wrenches, screw axes, exponential coordinates

of rigid body motion, adjoint transformation, Product of Exponentials (PoE) formulation, forward kinematics using PoE, comparison between Denavit–Hartenberg (DH) and Product of Exponentials (PoE) formulations; applications in robot modelling and control.

Trajectory planning; joint-space interpolation; task-space interpolation; cubic and quintic polynomial trajectories; trajectory generation; execution of user-specified tasks using joint-space and Cartesian-space trajectories.

UNIT – IV Robot Dynamics and Control

Static force analysis of RR and RP planar robots; generalized coordinates; body coordinate formulation; body-fixed and inertial reference frames; joint coordinate formulation; point coordinate formulation; dynamic analysis using Euler–Lagrange and Newton–Euler formulations; kinematic constraints (holonomic and non-holonomic); constrained equations of motion using Lagrange multipliers; applications of multibody formulations in robot modelling and simulation; actuator models; nonlinear characteristics of manipulator systems; independent joint control; PD and PID control; computed torque control; force control; hybrid position–force control; introduction to impedance control.

UNIT – V Robot Manipulation and Emerging Applications

Multi-fingered hand kinematics; grasping and manipulation; force closure; grasp planning; grasp constraints; robot hand dynamics; Lagrange equations with constraints; redundant manipulators; mobile manipulators; collaborative robots (Cobots); service robots; medical robots; intelligent robotic systems; digital twins in robotics; emerging trends in robotics and autonomous systems.

Software / Tools Required : MATLAB , Simulink, Robotics System Toolbox, ROS 2

Illustrative Case Studies

- SCARA Robot for Assembly , Forward & Inverse Kinematics of Industrial robots (ABB, KUKA) for specific applications, Position and force control of ABB, KUKA robots for specific applications, Vision-Based Robotic Sorting

NPTEL / SWAYAM Online Resources

- <https://nptel.ac.in/courses/112104316> (NOC: Advanced Robotics, IIT Kanpur)
- <https://nptel.ac.in/courses/112104620> (NOC: Advanced Robotics Applications, IIT Kanpur)

Professional Resources

- [IEEE Robotics and Automation Society](#), [International Federation of Robotics \(IFR\)](#)
- [ROS Official Website](#), [ABB Robotics](#), [KUKA Robotics](#)

Suggested Text Books

1. Mark W. Spong, Seth Hutchinson & M. Vidyasagar, Robot Modeling and Control, 2nd Edition, Wiley, 2020.
2. Kevin M. Lynch & Frank C. Park, Modern Robotics: Mechanics, Planning, and Control, Cambridge University Press, 2017.
3. John J. Craig, Introduction to Robotics: Mechanics and Control, 4th Edition, Pearson, 2018.
4. Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani & Giuseppe Oriolo, Robotics: Modelling, Planning and Control, Springer, 2009.
5. Richard M. Murray, Zexiang Li & S. Shankar Sastry, A Mathematical Introduction to Robotic Manipulation, CRC Press, 2017.
6. S. K. Saha, **Introduction to Robotics**, Tata McGraw-Hill.
7. John J. Craig, **Introduction to Robotics: Mechanics and Control**, Pearson.
8. Harry Asada and Jean-Jacques Slotine, **Robot Analysis and Control**, Wiley.

9. Ahmed A. Shabana, **Computational Dynamics**, Wiley.

Course Code ME 302	DRIVES AND MOTION CONTROL FOR AUTOMATION						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand industrial drives, actuators and motion control systems.
- Select suitable drive systems for robotic and automation applications.
- Design servo-based motion control systems.
- Integrate drives with automation controllers.
- Apply modern motion control technologies in robotics and smart manufacturing.

Course Outcomes; After successful completion of the course, students will be able to:

1. Select and analyze industrial drive systems for automation applications.
2. Design motion control systems using servo drives and feedback devices.
3. Analyze multi-axis motion control systems used in robotics and CNC machines.
4. Integrate drives with automation controllers and industrial systems.
5. Apply smart motion control technologies in robotics and Industry 4.0 applications.

UNIT – I Industrial Drives and Motion Actuators :

Fundamentals of electric drives, drive characteristics, torque-speed and power-speed characteristics, duty cycles and motor rating, selection and application of industrial drives. Operating principles, characteristics and applications of induction motors, BLDC motors, PMSM motors, servo motors, stepper motors, linear motors and frameless motors. Selection of drives for robotic systems, CNC machines, conveyor systems and automated manufacturing applications.

UNIT – II Motion Transmission and Feedback Systems

Motion transmission mechanisms including ball screw drives, rack and pinion systems, belt drives, gear drives, harmonic drives and planetary gear systems. Position feedback devices including encoders, resolvers and linear scales. Selection criteria for transmission and feedback systems used in industrial automation and robotic applications.

UNIT – III Servo Drives and Motion Control Systems

Position, velocity and torque control, servo amplifiers, servo tuning techniques, PID-based motion control, cascaded position-velocity-current control loops, motion profiles, trajectory generation, electronic gearing, electronic camming, multi-axis synchronization and industrial motion control applications.

UNIT – IV Automation Controllers and Industrial Integration

PLC fundamentals, motion PLCs, industrial controllers, machine sequencing, safety PLCs, integration of drives with PLCs and motion controllers, industrial control architectures, real-time control systems, applications in industrial robots, automated assembly systems and CNC machines.

UNIT – V Smart Motion Systems and Emerging Applications

Digital drives, intelligent servo systems, condition monitoring of drives, predictive maintenance, collaborative robots (Cobots), autonomous mobile robots (AMRs), digital twin technology, ROS2-based industrial automation and robot integration, intelligent motion systems and emerging trends in smart automation.

Software / Tools Required

MATLAB & Simulink, Simscape Electrical, Simscape Multibody, Siemens TIA Portal, CODESYS, Beckhoff TwinCAT 3, Factory I/O, ROS2, Gazebo, SOLIDWORKS.

Illustrative Case Studie

- Servo Drive-Based CNC Machine Control ,PLC-Based Conveyor Automation System , Multi-Axis Motion Control in Industrial Robots , Collaborative Robot (Cobot) Motion Control , Autonomous Mobile Robot (AMR) Navigation

NPTEL / SWAYAM Online Resources

- Fundamentals of Electric Drives — <https://nptel.ac.in/courses/108105017>
- Control Engineering — <https://nptel.ac.in/courses/108102044>
- Mechatronics — <https://nptel.ac.in/courses/112107298>

Suggested Learning Activities

- Servo Motor Performance Analysis
- PLC-Based Motion Control Programming
- Motion Transmission Mechanism Study
- Multi-Axis Motion Simulation
- Industrial Drive Selection Exercise
- Mini Project on Smart Motion Systems
- Seminar on Digital Twin and Smart Automation

Suggested Text Books

1. Gopal K. Dubey, Fundamentals of Electrical Drives, 2nd Edition, Narosa Publishing House, 2022 (Reprint).
2. Harvey Lehpamer, Servo Drives and Motion Control, CRC Press, 2017.
3. P. C. Sen, Principles of Electric Machines and Power Electronics, 3rd Edition, Wiley India, 2013.
4. I. J. Nagrath and M. Gopal, Control Systems Engineering, 7th Edition, New Age International, 2022.
5. Kevin M. Lynch and Frank C. Park, Modern Robotics: Mechanics, Planning, and Control, Cambridge University Press, 2017.
6. Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB®, 2nd Edition, Springer, 2017.

Course Code ME 303	EMBEDDED SYSTEMS AND EDGE COMPUTING FOR ROBOTICS (Programme Core)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

1. Understand the architecture and programming of embedded systems used in robotics and automation.
2. Develop real-time embedded applications using ARM-based microcontrollers and embedded operating systems.
3. Interface sensors, actuators and communication peripherals with embedded platforms.
4. Design embedded control systems for robotic and autonomous applications.
5. Apply edge computing concepts for intelligent robotic and automation systems.

Course Outcomes: After completing the course, students will be able to:

1. Analyze the architecture and operation of modern embedded systems and microcontrollers.
2. Develop embedded applications using ARM-based controllers and real-time operating systems.
3. Interface sensors, actuators and communication modules for robotic and automation systems.
4. Design embedded communication and monitoring systems for robotic applications.
5. Apply edge computing technologies for intelligent robotics and autonomous systems.

UNIT – I Embedded Systems Fundamentals and ARM Architecture

Introduction to embedded systems, characteristics of embedded systems, design metrics and design methodologies, hardware-software co-design, embedded system architecture, microcontrollers, microprocessors, DSPs and FPGAs, overview of ARM Cortex-M architecture, register organization, memory organization, interrupt architecture, development tools and IDEs, Embedded C programming fundamentals, real-time constraints in embedded systems, applications in robotics and automation.

UNIT – II Real-Time Embedded Systems and Programming

Embedded programming concepts, interrupt handling, timers and counters, Pulse Width Modulation (PWM), watchdog timers, real-time operating systems (RTOS), task scheduling concepts, inter-task communication, synchronization mechanisms, FreeRTOS fundamentals, real-time performance analysis, embedded software design for robotic and automation applications.

UNIT – III Sensors, Actuators and Embedded Interfacing

Interfacing of sensors and actuators, analog and digital sensors, encoders, inertial measurement units (IMU), ultrasonic sensors, LiDAR interfaces, ADC and DAC modules, DC motors, servo motors, stepper motors and BLDC motors, motor drivers, embedded motion control, signal conditioning, data acquisition systems, sensor calibration and error analysis, applications in robotic systems.

UNIT – IV Embedded Communication and Robotics Connectivity

Serial communication protocols: UART, SPI and I²C, CAN Bus architecture and applications, introduction to RS-485 and Modbus communication, wireless communication technologies including Wi-Fi and Bluetooth Low Energy (BLE), MQTT fundamentals, embedded networking concepts, IoT connectivity for automation systems, Micro-ROS and embedded robotics communication frameworks.

UNIT – V Edge Computing for Robotics and Intelligent Embedded Systems

Introduction to edge computing, edge devices for robotics, Raspberry Pi and NVIDIA Jetson platforms, Embedded Linux fundamentals, edge AI concepts, embedded vision systems, intelligent sensor networks, cloud and edge integration, cyber-physical systems, applications of edge computing in autonomous robots, smart manufacturing and Industry 4.0, introduction to TinyML and emerging trends in intelligent embedded systems.

Software / Tools Required; Keil µVision (MDK-ARM), STM32CubeIDE, MPLAB X IDE, FreeRTOS, Proteus Professional, MATLAB & Simulink, Arduino IDE, Raspberry Pi OS, NVIDIA JetPack SDK, VS Code

Illustrative Case Studies

- ARM Cortex-M Based Embedded Controller .FreeRTOS-Based Robot Control System .Sensor Interfacing for Mobile Robots ,IoT-Based Industrial Automation System . Edge AI for Autonomous Robot Applications

NPTEL / SWAYAM Online Resources

- Embedded System Design<https://nptel.ac.in/courses/106105193>
- Introduction to Internet of Things (IoT)<https://nptel.ac.in/courses/106105166>

Professional Resources

- [ARM Developer](#). [STMicroelectronics Developer Resources](#). [FreeRTOS](#)
- [ROS Official Website](#). [NVIDIA Developer](#)

Suggested Learning Activities

- ARM Cortex-M Programming Experiments
- FreeRTOS Task Scheduling Exercises
- Sensor and Actuator Interfacing Laboratory
- Embedded Communication Protocol Implementation
- Edge Computing Mini Project
- IoT-Based Embedded System Development
- Seminar on Industry 4.0 and Intelligent Embedded Systems

Reference Books

1. Jean J. Labrosse, *Embedded Systems Building Blocks: Complete and Ready-to-Use Modules in C*, 2nd Edition, CRC Press, 1999.
2. Qing Li and Caroline Yao, *Real-Time Concepts for Embedded Systems*, CMP Books, 2003.
3. Michael Barr and Anthony Massa, *Programming Embedded Systems: With C and GNU Development Tools*, 2nd Edition, O'Reilly Media, 2006.
4. Pete Warden and Daniel Situnayake, *TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers*, O'Reilly Media, 2019.
5. Frank Vasquez and Christopher Simmonds, *Mastering Embedded Linux Programming*, 3rd Edition, Packt Publishing, 2021.
6. Raj Kamal, *Embedded Systems: Architecture, Programming and Design*, 4th Edition, McGraw Hill Education, 2019.
7. Shibu K. V., *Introduction to Embedded Systems*, 2nd Edition, McGraw Hill Education, 2017.
8. Himanshu B. Dave, *Embedded Systems: Concepts, Design and Programming*, Pearson India, 2015.
9. Saurabh Chandrakar and Nilesch Bhaskarrao Bahadure, *Microcontrollers and Embedded System Design*, Dreamtech Press, 2019.
10. Ajay V. Deshmukh, *Microcontrollers: Theory and Applications*, McGraw Hill Education, 2017.

Course Code ME 311	FINITE ELEMENT TECHNIQUES (Program Elective - I)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the fundamentals of finite element analysis and its engineering applications.
- Develop finite element formulations for structural, thermal and dynamic problems.
- Analyze one-dimensional and two-dimensional engineering systems using finite element techniques.
- Apply finite element methods for vibration, thermal and stress analysis.
- Utilize finite element tools for robotic, mechanical and autonomous system design.

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

1. Explain the mathematical foundations and formulation of the finite element method.
2. Develop finite element models for one-dimensional and two-dimensional engineering problems.
3. Analyze structural, thermal and dynamic systems using finite element techniques.
4. Apply finite element methods to vibration and stress analysis of engineering components.
5. Evaluate robotic and mechanical systems using commercial finite element analysis tools.

UNIT – I Fundamentals of Finite Element Method

Introduction to finite element analysis, historical development, mathematical modeling of engineering field problems, governing equations, discrete and continuous systems, boundary and initial value problems, weighted residual methods, Galerkin method, variational formulation, finite element formulation, strain-displacement relationships, stress-strain relationships, interpolation functions, element discretization, assembly procedures and treatment of boundary conditions.

UNIT – II One-Dimensional Finite Elements

Finite element formulation of bar elements, truss elements, beam elements and frame elements, local and global coordinate systems, element stiffness matrices, force-displacement relationships, higher-order one-dimensional elements, analysis of trusses, beams and frames,

UNIT – III Two-Dimensional Finite Elements

Constant strain triangle (CST) elements, four-noded quadrilateral element, isoparametric formulation, numerical integration concepts, plane stress problems, plane strain problems, axisymmetric problems, body forces and thermal loading, stress recovery, convergence requirements, higher-order elements and applications in structural analysis.

UNIT – IV Thermal and Dynamic Finite Element Analysis

Steady-state heat transfer analysis, one-dimensional heat conduction, fin analysis, composite wall analysis, two-dimensional heat conduction problems, transient heat transfer analysis,

finite element formulation of dynamic systems, eigenvalue problems, natural frequencies and mode shapes, modal analysis and vibration analysis of engineering structures.

UNIT – V: Commercial FEA Software and Engineering Applications

Three-dimensional finite element analysis, basic three-dimensional stress analysis, introduction to inviscid fluid flow analysis- stream functions, velocity potential, CAD–FEA integration, mesh generation and mesh quality, introduction to nonlinear finite element analysis, commercial FEA software (ANSYS, Abaqus, HyperMesh and SolidWorks Simulation), post-processing and interpretation of results, and engineering applications in machine design, manufacturing, automotive, aerospace and robotics.

Software / Tools Required. ANSYS Mechanical, Abaqus, HyperMesh, SolidWorks Simulation, MATLAB, COMSOL Multiphysics, Autodesk Fusion 360, CATIA, MSC Nastran/Patran, Altair HyperView

Illustrative Case Studies

- Stress Analysis of a Cantilever Beam ,Finite Element Analysis of a Robotic Arm
- Thermal Analysis of Engineering Components ,Modal Analysis of Machine Structures, CAD–FEA Integration for Product Design

NPTEL / SWAYAM Online Resources

- Finite Element Analysis<https://nptel.ac.in/courses/112104116>
- Advanced Finite Element Analysis<https://nptel.ac.in/courses/112104030>
- Computer Aided Engineering Design<https://nptel.ac.in/courses/112104216>

Professional Resources

- [ANSYS Learning Resources](#), [Dassault Systèmes SIMULIA \(Abaqus\)](#), [Altair HyperWorks](#), [SolidWorks Simulation](#), [NAFEMS](#)

Suggested Learning Activities

- Finite Element Modeling of Structural Members, One-Dimensional Element Analysis
- Two-Dimensional Stress Analysis, Thermal and Modal Analysis Using FEA
- CAD–FEA Integration Exercises, Mesh Generation and Quality Assessment
- Mini Project on Robotic Structure Analysis.

Reference Books

1. T. R. Chandrupatla and Ashok D. Belegundu, *Introduction to Finite Elements in Engineering*, 5th Edition, Cambridge University Press, 2022.
2. P. Seshu, *Textbook of Finite Element Analysis*, PHI Learning Pvt. Ltd., 2013.
3. C. S. Krishnamoorthy, *Finite Element Analysis: Theory and Programming*, 2nd Edition, McGraw-Hill Education (India), 2004.
4. J. N. Reddy, *An Introduction to the Finite Element Method*, 4th Edition, McGraw-Hill Education, 2019.
5. O. C. Zienkiewicz, R. L. Taylor, and S. Govindjee, *The Finite Element Method: Its Basis and Fundamentals*, 8th Edition, Elsevier, 2024.
6. Daryl L. Logan, *A First Course in the Finite Element Method*, 7th Edition, Cengage Learning, 2022.
7. Robert D. Cook, David S. Malkus, Michael E. Plesha, and Robert J. Witt, *Concepts and Applications of Finite Element Analysis*, 4th Edition, Wiley, 2002.
8. Saeed Moaveni, *Finite Element Analysis: Theory and Application with ANSYS*, 4th Edition, Pearson, 2015.

Course Code ME 312	ROBOT PERCEPTION, SENSING AND COMPUTER VISION (Programme Elective - I)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
		3	-	-	3	40	60

Course Objectives

- Understand the principles of robotic sensing, perception and computer vision.
- Learn image processing and computer vision techniques for autonomous robotic systems.
- Study camera models, visual perception and 3D scene understanding.
- Understand localization, mapping and visual navigation techniques.
- Apply machine learning and deep learning methods for robotic perception applications.

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

1. Identify and analyze sensing technologies used in robotic systems.
2. Apply image processing and computer vision techniques for robotic perception.
3. Develop algorithms for pose estimation, visual odometry and 3D scene understanding.
4. Implement localization, mapping and visual SLAM techniques for autonomous robotic systems.
5. Apply deep learning methods for object recognition, scene understanding and intelligent robotic perception.

UNIT – I Robotic Sensors and Perception Systems

Introduction to robotic perception, sensing and perception architecture, perception pipeline for autonomous systems, sensing principles and sensor characteristics, RGB cameras, stereo cameras, RGB-D cameras, event cameras, LiDAR, ultrasonic sensors, IMU, GPS, force and tactile sensors, sensor calibration, sensor fusion fundamentals, applications of perception in mobile robots, manipulators, autonomous vehicles and drones.

UNIT – II Computer Vision Fundamentals

Image acquisition and representation, image enhancement and filtering, edge detection, feature extraction, feature descriptors, image segmentation, morphological operations, camera models, camera calibration, homogeneous coordinates, single-view geometry, feature matching, RANSAC, introduction to multiple-view geometry and 3D vision.

UNIT – III Visual Perception and 3D Scene Understanding

Pose estimation, visual tracking, motion estimation, structure from motion, visual odometry, stereo vision, depth estimation, dense and sparse reconstruction, point cloud processing, object tracking, scene representation and 3D environment modeling for robotic systems.

UNIT – IV Localization, Mapping and Visual SLAM

Localization techniques, probabilistic localization concepts, occupancy grid mapping, Kalman Filter and Particle Filter concepts, Simultaneous Localization and Mapping (SLAM),

Visual SLAM, LiDAR SLAM, Graph-based SLAM concepts, ORB-SLAM architecture, loop closure detection, map optimization, sensor fusion for localization and navigation in dynamic environments.

UNIT – V Deep Learning for Robotic Vision

Machine learning and deep learning for perception, Convolutional Neural Networks (CNNs), object detection, semantic segmentation, introduction to visual transformers, multimodal perception, scene understanding, embodied perception, perception for autonomous vehicles, drones, industrial robots and service robots, emerging trends in robotic vision and intelligent perception systems.

Suggested Text Books

1. Richard Szeliski, *Computer Vision: Algorithms and Applications*, 2nd Edition, Springer, 2022.
2. Rafael C. Gonzalez and Richard E. Woods, *Digital Image Processing*, 4th Edition, Pearson Education, 2018.
3. Simon J. D. Prince, *Computer Vision: Models, Learning, and Inference*, 2nd Edition, Cambridge University Press, 2023.
4. Sebastian Thrun, Wolfram Burgard, and Dieter Fox, *Probabilistic Robotics*, MIT Press, 2005.
5. Richard Hartley and Andrew Zisserman, *Multiple View Geometry in Computer Vision*, 2nd Edition, Cambridge University Press, 2004.
6. Peter Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB®*, 2nd Edition, Springer, 2017.
7. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer,

2016. Software / Tools Required

- OpenCV, ROS2, Gazebo, RViz, MATLAB, Python (Anaconda, Jupyter Notebook), TensorFlow, PyTorch, NVIDIA Isaac Sim, ORB-SLAM3

Illustrative Case Studies

- Vision-Based Object Detection for Robots , Visual SLAM for Mobile Robots
- Autonomous Drone Navigation Using Computer Vision , LiDAR-Based Mapping and Localization , Deep Learning-Based Industrial Inspection

NPTEL / SWAYAM Online Resources

1. Computer Vision <https://nptel.ac.in/courses/106106224>
2. Artificial Intelligence: Search Methods for Problem Solving <https://nptel.ac.in/courses/106105079>
3. Deep Learning <https://nptel.ac.in/courses/106106184>

Professional Resources

- [OpenCV Documentation](#), [ROS Official Website](#), [Point Cloud Library \(PCL\)](#), [TensorFlow](#), [PyTorch](#)

Suggested Learning Activities

- Image Processing Experiments, Camera Calibration and Pose Estimation
- Feature Detection and Object Tracking, Visual SLAM Simulation
- Point Cloud Processing Exercises, Deep Learning-Based Vision Project , Seminar on Autonomous Perception Systems

Course Code ME313	INDUSTRY 4.0 and SMART MANUFACTURING (Programme Elective - I)						CourseType Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the concepts, architecture and enabling technologies of Industry 4.0.
- Learn the role of Industrial Internet of Things (IIoT), Cyber-Physical Systems, Robotics and Digital Twins in smart manufacturing.
- Understand the application of artificial intelligence, machine learning and data analytics in modern industries.
- Analyze smart factory technologies, digital manufacturing systems and intelligent production processes.
- Develop knowledge of cybersecurity, industrial communication and future manufacturing systems.

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

1. Explain the concepts, architecture and enabling technologies of Industry 4.0.
2. Apply Industrial IoT, cyber-physical systems and data analytics in manufacturing environments.
3. Analyze the role of robotics, artificial intelligence and digital twins in smart factories.
4. Evaluate additive manufacturing, cloud manufacturing and intelligent production systems.
5. Assess cybersecurity challenges and emerging technologies in Industry 4.0 and Industry 5.0 environments.

UNIT – I Introduction to Industry 4.0 and Smart Manufacturing

Evolution of industrial revolutions, Industry 4.0 architecture, key enabling technologies, cyber-physical systems (CPS), smart factories, digital manufacturing, connected products, smart supply chains, lean and agile manufacturing, business models in Industry 4.0, Industry 4.0 laboratories, opportunities and challenges in digital transformation, future skills required for Industry 4.0 workforce and strategies for competing in a digital manufacturing environment.

UNIT – II Industrial Internet of Things and Data Analytics

Industrial Internet of Things (IIoT) architecture, smart sensors and actuators, industrial communication concepts, OPC-UA and MQTT protocols, edge and cloud computing, data acquisition systems, industrial big data, manufacturing data analytics, predictive analytics, predictive maintenance, forecasting concepts, industrial case studies, security and privacy concerns in connected manufacturing systems.

UNIT – III Robotics, Artificial Intelligence and Smart Automation

Industrial robots, collaborative robots (Cobots), autonomous mobile robots (AMRs), Internet of Robotic Things (IoRT), machine vision systems, intelligent inspection systems, introduction to artificial intelligence and machine learning in manufacturing, human-robot

collaboration, cloud robotics, augmented reality and virtual reality in manufacturing, smart automation systems and industrial applications.

UNIT – IV Digital Twins and Advanced Manufacturing Technologies

Digital twin concepts and architecture, virtual commissioning, simulation-based manufacturing, cloud manufacturing, additive manufacturing technologies, smart production systems, digital traceability, product lifecycle management (PLM), sustainable manufacturing, applications of additive manufacturing in medical, aerospace, automotive and electronics industries, applications of digital twins in manufacturing, robotics and autonomous systems.

UNIT – V Cybersecurity and Future Manufacturing Systems

Cybersecurity fundamentals, security threats and vulnerabilities in industrial systems, secure industrial networks, industrial cyber-attacks and case studies, risk assessment and mitigation strategies, blockchain in manufacturing, virtual factory concepts, Industry 5.0, human-centric manufacturing, green manufacturing, generative AI applications in manufacturing, future trends in smart factories and autonomous production systems.

Software / Tools Required

Siemens TIA Portal, Rockwell Studio 5000, CODESYS, MATLAB & Simulink, Python (TensorFlow, PyTorch, Scikit-learn), Node-RED, Kepware OPC UA Server, Ignition SCADA, MQTT Broker (Mosquitto), Power BI, Tableau, ROS2, Gazebo, NVIDIA Isaac Sim, AWS IoT Core, Azure IoT Hub, Docker, Kubernetes

Illustrative Case Studies

- Smart Factory Implementation Using Industry 4.0
- Predictive Maintenance in Industrial Machinery
- Digital Twin for Manufacturing Systems
- IIoT-Based Smart Supply Chain System
- Collaborative Robot (Cobot) Assembly Line Automation

NPTEL / SWAYAM Online Resources

1. Introduction to Industry 4.0 and Industrial Internet of Things — <https://nptel.ac.in/courses/106105195>
2. Cyber Security and Privacy — <https://nptel.ac.in/courses/106106129>
3. Machine Learning for Engineering and Science Applications — <https://nptel.ac.in/courses/106106139>

Professional Resources

- [IEEE Industrial Electronics Society](#)
- [International Society of Automation](#)
- [Siemens Digital Industries](#)
- [Rockwell Automation](#)
- Microsoft Azure IoT
- PTC ThingWorx

Suggested Learning Activities

- IIoT Sensor Data Collection and Visualization
- PLC-Based Smart Automation Project
- Digital Twin Modeling Exercise
- Predictive Maintenance Case Study

Suggested Text Books

1. Alasdair Gilchrist, *Industry 4.0: The Industrial Internet of Things*, Apress, 2016.
2. Alp Ustundag and Emre Cevikcan, *Industry 4.0: Managing the Digital Transformation*, Springer, 2018.
3. Pascual D. G. (Ed.), *Handbook of Industry 4.0 and Smart Systems*, CRC Press, 2022.
4. Klaus Schwab, *The Fourth Industrial Revolution*, Crown Business, 2017.
5. Mikell P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, 5th Edition, Pearson, 2020.
6. Kumar K., *Digital Manufacturing and Assembly Systems in Industry 4.0*, CRC Press, 2022.
7. Sabina Jeschke, Christian Brecher, Houbing Song, and Danda B. Rawat (Eds.), *Industrial Internet of Things: Cybermanufacturing Systems*, Springer, 2017.
8. Oliver Niggemann (Ed.), *Digital Twins: Applications to the Built Environment and Industry 4.0*, Springer, 2023.
9. Jay Lee, Chao Jin, Zongchang Liu, and Hossein Davari Ardakani, *Industrial AI: Applications with Sustainable Performance*, Springer, 2024.

Course Code ME 314	VIRTUAL REALITY, AUGMENTED REALITY AND DIGITAL TWIN SYSTEMS (Program Elective – I)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the fundamentals of Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and Digital Twin technologies.
- Learn hardware and software technologies used in immersive environments.
- Understand tracking, visualization and interaction techniques used in VR/AR systems.
- Apply VR/AR technologies in robotics, manufacturing, maintenance and training applications.
- Design Digital Twin solutions for smart manufacturing, robotics and Industry 4.0 applications.

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

1. Differentiate between Virtual Reality, Augmented Reality, Mixed Reality and Digital Twin technologies.
2. Develop immersive virtual environments using modern VR/AR development platforms.
3. Analyze tracking, localization and interaction techniques used in immersive systems.
4. Apply VR/AR technologies in robotics, manufacturing, maintenance and training applications.
5. Design Digital Twin solutions for smart factories, robotic systems and Industry 4.0 environments.

UNIT – I Introduction to Virtual, Augmented and Mixed Reality

Evolution of immersive technologies, Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) concepts, components of VR/AR systems, human perception and immersion, VR hardware and software architecture, head mounted displays (HMDs), motion tracking systems, controllers and haptic devices, applications of VR/AR in engineering, healthcare, robotics, education and manufacturing.

UNIT – II 3D Modelling, Visualization and Immersive Environment Development

Fundamentals of 3D graphics, coordinate systems and transformations, virtual environment development, Unity game engine fundamentals, introduction to Unreal Engine, object modelling, scene creation, user interfaces in immersive environments, interaction techniques, gesture-based interaction, voice interaction and user experience design principles for VR/AR systems.

UNIT – III Tracking, Localization and Interaction Technologies

Camera models, marker-based and markerless tracking, sensor-based tracking systems, depth sensing technologies, LiDAR-based tracking, sensor fusion concepts, hand tracking, eye

tracking, spatial mapping, object recognition, introduction to SLAM for AR/VR applications, localization and interaction techniques for immersive systems.

UNIT – IV VR/AR Applications in Robotics and Manufacturing

Robotics simulation environments, digital prototyping, virtual commissioning, Human-Robot Interaction (HRI), teleoperation and telerobotics, AR-assisted maintenance and assembly, training simulators, collaborative robot visualization, industrial inspection and quality control, smart manufacturing applications and virtual training environments.

UNIT – V Digital Twins and Industrial Metaverse

Digital Twin concepts, architecture and lifecycle, real-time synchronization principles, virtual factories, Digital Twin applications in manufacturing and robotics, Cyber-Physical Systems (CPS), Industrial Metaverse concepts, remote monitoring and control, cloud-based simulation environments, smart factories, Industry 4.0 and Industry 5.0 applications, future trends in immersive technologies and digital engineering systems.

Software / Tools Required

Unity 3D, Unreal Engine, Blender, Autodesk Maya, Vuforia, ARCore, ARKit, OpenXR, ROS2, Gazebo, NVIDIA Omniverse, MATLAB & Simulink, Python (OpenCV), WebXR, Microsoft Mesh

Illustrative Case Studies

- Virtual Reality Training Simulator ,AR-Based Maintenance and Assembly , Digital Twin for Smart Manufacturing , Human–Robot Interaction in VR, Virtual Commissioning of Industrial Systems

NPTEL / SWAYAM Online Resources

1. Virtual Reality <https://nptel.ac.in/courses/106105167>
2. Augmented Reality and Virtual Reality <https://nptel.ac.in/courses/106106241>
3. Computer Graphics <https://nptel.ac.in/courses/106106197>

Professional Resources

1. [Unity Learn](#), [Unreal Engine Documentation](#), [OpenXR](#), [ROS Official Website](#), [NVIDIA Omniverse](#)

Suggested Learning Activities

- VR/AR Application Development ,3D Environment Design Using Unity , Marker-Based AR Experiments, Robot Simulation in Virtual Environments , Digital Twin Mini Project .

Reference Books

1. Grigore C. Burdea and Philippe Coiffet, *Virtual Reality Technology*, 2nd Edition, Wiley-IEEE Press, 2003.
2. Oliver Niggemann (Ed.), *Digital Twins: Applications to the Built Environment and Industry 4.0*, Springer, 2023.
3. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
4. Unity Technologies, *Unity User Manual and Documentation*, Unity Technologies, Latest Online Edition.
5. Epic Games, *Unreal Engine Documentation*, Epic Games, Latest Online Edition.
6. Frank Delaney and Peter Van Dongen, *Digital Twin Technologies and Smart Manufacturing Systems*, CRC Press, 2024.
7. Michael Hook, *Beginning Unity: A Practical Guide to Game Development*, 3rd Edition, Apress, 2023.
8. John Vince, *Virtual Reality Systems*, Addison-Wesley, 2017.
9. Erik Guilfoyle, *Industry 4.0 and the Digital Twin: Manufacturing in the Digital Age*, Mercury Learning and Information, 2022.
10. Alessandro Canetta, Sergio Terzi, and Marco Taisch (Eds.), *Digital Twin Driven Smart Manufacturing*, Springer, 2024.

Course Code ME 315	PYTHON PROGRAMMING FOR ROBOTICS (Program Elective – I)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

1. Understand Python programming concepts for robotic applications.
2. Develop object-oriented Python programs for robot modeling and control.
3. Apply Python scientific libraries for robotic computations and data visualization.
4. Implement robot kinematics, perception, and autonomous navigation algorithms using Python.
5. Develop ROS 2-based robotic applications for industrial and autonomous robots.

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

1. Develop Python programs using procedural and object-oriented programming concepts for robotic applications.
2. Apply Python scientific computing libraries for robot data analysis, visualization, and numerical computations.
3. Implement robot kinematics, trajectory planning, and simulation using Python-based robotics frameworks.
4. Develop computer vision and AI-based perception algorithms for robotic systems using Python.
5. Design and implement ROS 2-based autonomous robotic applications using Python.

UNIT – I: Python Programming Fundamentals

Introduction to Python, installation and development environments (VS Code, PyCharm, Jupyter Notebook), variables, data types, operators, input/output, strings, lists, tuples, dictionaries, sets, control structures, functions, modules and packages, exception handling, file handling, debugging techniques, introduction to NumPy.

UNIT – II: Object-Oriented Programming and Scientific Computing

Object-oriented programming concepts, classes and objects, constructors, inheritance, polymorphism, encapsulation, iterators, generators, virtual environments, package management using pip, numerical computing using NumPy and SciPy, data analysis using Pandas, data visualization using Matplotlib and Plotly, robot data logging and analysis.

UNIT – III: Python for Robot Modeling and Motion Planning

Coordinate frames and homogeneous transformations, Denavit–Hartenberg (DH) parameters, forward and inverse kinematics, Jacobian matrix, differential kinematics, trajectory generation, robot workspace analysis, Robotics Toolbox for Python, PyBullet simulation, RobotDK Python API.

UNIT – IV: Robot Perception and Artificial Intelligence using Python

Image processing using OpenCV, camera calibration, feature extraction, object detection, ArUco and AprilTag markers, deep learning for robotics using PyTorch and TensorFlow, YOLO-based object detection, LiDAR data processing, point cloud processing, sensor fusion, introduction to reinforcement learning for autonomous robots.

UNIT – V: Python Programming with ROS 2

Introduction to ROS 2 architecture, Python nodes, publishers and subscribers, services, actions, parameters, TF2 transformations, launch files, robot control using Python, Navigation2 (Nav2), MoveIt Python interface, Gazebo simulation, autonomous mobile robots, collaborative robots, industrial robot programming, drone applications using Python.

Software / Tools Required

Python 3.x, Visual Studio Code (VS Code)/PyCharm, Jupyter Notebook, Anaconda, NumPy, SciPy, Pandas, Matplotlib, OpenCV, Scikit-learn, PyTorch/TensorFlow, Robotics Toolbox for Python, PyBullet, RobotDK, ROS 2 (Humble/Jazzy), Gazebo Sim, RViz2, MoveIt 2, and Git.

Illustrative Case Studies

Python-based control of a differential drive mobile robot., Robotic manipulator kinematics using Robotics Toolbox for Python., Autonomous navigation of a mobile robot using ROS 2 and Python., Object detection and tracking using OpenCV and YOLO for robotic applications., Pick-and-place robot programming using RobotDK Python API., Vision-guided robotic sorting using Python and computer vision., LiDAR-based obstacle detection and avoidance using Python. Trajectory planning and simulation of robotic manipulators using PyBullet., Reinforcement learning for autonomous robot navigation., Python-based drone navigation and waypoint planning using ROS 2.

NPTEL / SWAYAM Online Resources

2. The Joy of Computing using Python – Prof. S. R. S. Iyengar, IIT Ropar.
3. Programming, Data Structures and Algorithms using Python – Prof. Madhavan Mukund, IIT Madras.
4. Introduction to Machine Learning – Prof. Balaraman Ravindran, IIT Madras.
5. Introduction to Robotics – Prof. Ravi Balasubramanian, IIT Roorkee.
6. Robot Kinematics and Dynamics – Prof. Ravi Balasubramanian, IIT Roorkee. Professional Resources

Suggested Learning Activities

Develop Python programs for solving engineering and robotics problems. , Implement object-oriented programming concepts for robotic applications. , Perform numerical computations and data visualization using NumPy, SciPy, Pandas, and Matplotlib., Model and simulate robot kinematics using the Robotics Toolbox for Python. Develop computer vision applications using OpenCV for object detection and tracking., Implement basic machine learning algorithms for robotic perception and decision-making. Develop ROS 2 Python nodes for robot communication, control, and navigation. Simulate autonomous mobile robots using Gazebo, RViz2, and PyBullet.

Reference Books

1. Peter Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB® and Python*, 3rd Edition, Springer, 2023.
2. Mark Lutz, *Learning Python*, 6th Edition, O'Reilly Media, 2024.
3. Luciano Ramalho, *Fluent Python*, 2nd Edition, O'Reilly Media, 2022.
4. Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017.
5. Al Sweigart, *Automate the Boring Stuff with Python*, 3rd Edition, No Starch Press, 2025.
6. Charles R. Severance, *Python for Everybody: Exploring Data Using Python 3*, 2nd Edition, PY4E, 2023.
7. Alessandro Canetta, Sergio Terzi, and Marco Taisch (Eds.), *Digital Twin Driven Smart Manufacturing*, Springer, 2024.

Course Code ME316	MECHATRONICS (Programme Elective - I)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

1. Understand the fundamentals and architecture of mechatronic systems.
2. Learn sensors, actuators, embedded controllers, and industrial communication.
3. Analyze modeling, control, and integration of mechatronic systems.
4. Apply mechatronic principles to robotics and industrial automation.
5. Explore intelligent mechatronic systems for Industry 4.0 applications.

Course Outcomes (COs) After successful completion of the course, the student will be able to:

1. Explain the architecture and components of mechatronic systems.
2. Select and integrate sensors, actuators, embedded controllers, and industrial communication systems.
3. Model and analyze mechatronic systems using appropriate control techniques.
4. Apply mechatronic principles in robotics and industrial automation systems.
5. Evaluate intelligent mechatronic systems incorporating IoT, AI, and Industry 4.0 technologies.

UNIT – I: Fundamentals of Mechatronic Systems

Introduction to mechatronics, system architecture, mechanical, electrical and electronic elements, sensors and transducers, signal conditioning, data acquisition systems, electric, hydraulic and pneumatic actuators, selection of sensors and actuators, engineering applications.

UNIT – II: Embedded Systems and Industrial Communication

Microcontrollers and embedded systems, input/output interfacing, A/D and D/A converters, timers and interrupts, programmable logic controllers (PLC), industrial communication protocols (Modbus, CAN, EtherCAT), Human Machine Interface (HMI), SCADA systems, Industrial Internet of Things (IIoT).

UNIT – III: Mechatronic System Modeling and Control

Mathematical modeling of mechatronic systems, transfer function models, state-space representation, feedback control, PID controllers, servo systems, motion control, stepper and servo motor control, real-time control systems, system integration.

UNIT – IV: Mechatronics in Robotics and Automation

Robot sensors, end-effectors, industrial robot drives, robotic manipulators, machine vision, flexible manufacturing systems (FMS), CNC automation, Automated Guided Vehicles

(AGVs), collaborative robots (Cobots), autonomous mobile robots (AMRs), robotic work cells.

UNIT – V: Intelligent Mechatronic Systems

Cyber-Physical Systems (CPS), digital twins, intelligent monitoring, condition monitoring and predictive maintenance, IoT-enabled mechatronic systems, machine learning applications in automation, smart manufacturing, edge computing, AI-assisted control systems, emerging trends in intelligent mechatronics.

Software / Tools Required

Siemens TIA Portal, Rockwell Studio 5000, CODESYS, MATLAB & Simulink, Python (TensorFlow, PyTorch, Scikit-learn), Node-RED, Kepware OPC UA Server, Ignition SCADA, MQTT Broker (Mosquitto), Power BI, Tableau, ROS2, Gazebo, NVIDIA Isaac Sim, AWS IoT Core, Azure IoT Hub, Docker, Kubernetes

Illustrative Case Studies

- Smart Factory Implementation Using Industry 4.0
- Predictive Maintenance in Industrial Machinery
- Digital Twin for Manufacturing Systems
- IIoT-Based Smart Supply Chain System
- Collaborative Robot (Cobot) Assembly Line Automation

NPTEL / SWAYAM Online Resources

4. Introduction to Industry 4.0 and Industrial Internet of Things — <https://nptel.ac.in/courses/106105195>
5. Cyber Security and Privacy — <https://nptel.ac.in/courses/106106129>
6. Machine Learning for Engineering and Science Applications — <https://nptel.ac.in/courses/106106139>

Professional Resources

- [IEEE Industrial Electronics Society](#)
- [International Society of Automation](#)
- [Siemens Digital Industries](#)
- [Rockwell Automation](#)
- Microsoft Azure IoT
- PTC ThingWorx

Suggested Learning Activities

- IIoT Sensor Data Collection and Visualization
- PLC-Based Smart Automation Project
- Digital Twin Modeling Exercise
- Predictive Maintenance Case Study

Suggested Text Books

1. **W. Bolton**, *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, **8th Edition**, Pearson Education, **2023**.

2. **David G. Alciatore and Michael B. Histanb**, *Introduction to Mechatronics and Measurement Systems*, **6th Edition**, McGraw-Hill Education, **2024**.
3. **Biswanath Samanta**, *Introduction to Mechatronics: An Integrated Approach*, Springer Nature, **2024**.
4. **Tilak Thakur**, *Mechatronics*, Oxford University Press, **2015**.
5. **Devdas Shetty and Richard A. Kolk**, *Mechatronics System Design*, **2nd Edition**, Cengage Learning, **2011**.
6. **Clarence W. de Silva**, *Mechatronics: An Integrated Approach*, **2nd Edition**, CRC Press, **2015**.
7. **Robert H. Bishop (Ed.)**, *The Mechatronics Handbook*, CRC Press, **2018**.
8. **Ajay Kumar, Parveen Kumar and Aydin Azizi (Eds.)**, *Advances in Mechatronics Systems: Principles, Elements and Applications*, Springer Nature, **2024**.

Course Code ME 317	WEARABLE ROBOTICS AND EXOSKELETON SYSTEMS (Programme Elective - II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the biomechanical principles relevant to wearable robotics and exoskeleton systems.
- Learn the design, modeling and development of upper-limb and lower-limb exoskeletons.
- Study sensors, actuators and human-machine interfaces used in wearable robotic systems.
- Develop control strategies for human-in-the-loop and assistive robotic systems.
- Apply wearable robotic technologies in rehabilitation, industrial assistance and human augmentation applications.

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

1. Analyze human biomechanics and motion characteristics relevant to wearable robotic systems.
2. Select appropriate sensors, actuators and transmission systems for exoskeleton design.
3. Design and model upper-limb and lower-limb wearable robotic systems.
4. Develop control strategies for rehabilitation and assistive exoskeletons.
5. Evaluate wearable robotic systems for rehabilitation, industrial and human augmentation applications.

UNIT – I Human Biomechanics for Wearable Robotics

Introduction to wearable robotics and exoskeleton systems, anthropometry, human musculoskeletal system, biomechanics of upper-limb and lower-limb joints, range of motion analysis, human gait fundamentals, walking and running biomechanics, ergonomic considerations, human motion characteristics, biomechanical requirements for wearable robot design.

UNIT – II Sensors and Actuators for Wearable Systems

Wearable sensing technologies, inertial measurement units (IMU), force and torque sensors, pressure sensors, flex sensors, electromyography (EMG) sensors, sensor placement and calibration. Actuation technologies including DC motors, servo motors, brushless motors, cable-driven systems, series elastic actuators, pneumatic artificial muscles, shape memory alloy (SMA) actuators, soft actuators and actuator selection for wearable robotics.

UNIT – III Exoskeleton Design and Mechanical Systems

Classification of exoskeletons, upper-limb and lower-limb exoskeleton architectures, kinematic compatibility and joint alignment, mechanical design considerations, lightweight structures and materials, transmission mechanisms, cable-driven systems, tendon-driven systems, wearable robotic gloves, hand exoskeletons, power supply systems, safety, reliability and ergonomic design considerations.

UNIT – IV Human-Robot Interaction and Control of Exoskeletons

Human intention detection, EMG-based control concepts, force and torque control, impedance and admittance control, assist-as-needed strategies, human-in-the-loop control, shared control systems, sensor fusion for wearable robotics, gait assistance control, rehabilitation control strategies, safety and stability considerations in wearable robotic systems.

UNIT – V Rehabilitation, Industrial and Human Augmentation Applications

Rehabilitation robotics and assistive technologies, robotic prostheses, upper-limb rehabilitation robots, lower-limb rehabilitation exoskeletons, industrial exoskeletons for worker assistance, military and defense exoskeletons, wearable soft robots, human augmentation systems, clinical evaluation methods, standards and safety guidelines, commercial exoskeleton case studies, emerging trends in wearable robotics and human augmentation technologies.

Software / Tools Required

Fusion 360, ANSYS, ROS2, Gazebo, OpenSense (OpenSim Toolkit), OpenSim GUI tools
MATLAB & Simulink, Python (Anaconda, Jupyter Notebook), OpenSim, AnyBodyModeling System, SolidWorks, Autodesk

Illustrative Case Studies

- Lower-Limb Rehabilitation Exoskeleton
- EMG-Controlled Robotic Hand
- Industrial Worker Assistance Exoskeleton
- Wearable Robotic Glove for Hand Rehabilitation
- Soft Robotic Exosuit for Gait Assistance

NPTEL / SWAYAM Online Resources

- Rehabilitation Robotics — <https://nptel.ac.in/courses/112104251>
- Human-Centered Robotics — <https://nptel.ac.in/courses/112105297>
- Biomechanics and Biomedical Engineering — <https://nptel.ac.in/courses/102103081>

Professional Resources

- [IEEE Robotics and Automation Society](#)
- [International Society of Biomechanics](#)
- [OpenSim](#)
- [ROS Official Website](#)
- [ReWalk Robotics](#)

Suggested Learning Activities

- Human Gait Analysis Laboratory
- Wearable Sensor Integration Experiments
- Exoskeleton Mechanism Design Exercise
- EMG-Based Control Demonstration

Suggested Text Books

1. José L. Pons, *Wearable Robots: Biomechatronic Exoskeletons*, Wiley, 2008.
2. Homer H. Chen and Yobing Shi (Eds.), *Wearable Robotics: Challenges and Trends*, Springer, 2017.
3. Rory A. Cooper, Hisaichi Ohnabe, and Douglas A. Hobson, *An Introduction to Rehabilitation Engineering*, 2nd Edition, CRC Press, 2006.
4. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
5. Paolo Bonato (Ed.), *Wearable Sensors and Systems for Rehabilitation*, Springer, 2018.
6. Sashi S. Kommu (Ed.), *Rehabilitation Robotics*, IntechOpen, 2007.
7. David A. Winter, *Biomechanics and Motor Control of Human Movement*, 4th Edition, Wiley, 2009.
8. Gordon Cheng, *Humanoid Robotics and Neuroscience: Science, Engineering and Society*, CRC Press, 2018.
9. Miguel A. Otaduy and Josep M. Font-Llagunes (Eds.), *Human-Centered Robotics and Wearable Systems*, Springer, 2024.
10. Arianna Menciassi and Paolo Dario, *Wearable Robotics: From Science to Applications*, Springer, 2021.
11. Paolo Bonato, *Advances in Wearable Technology and Rehabilitation Engineering*, Springer, 2020.
12. Carlo Menon and E. Burdet (Eds.), *Rehabilitation Robotics*, Academic Press, 2022.
13. □ Rory A. Cooper, Hisaichi Ohnabe, and Douglas A. Hobson, *Rehabilitation Engineering Applied to Mobility and Manipulation*, CRC Press, 2019.

Course Code ME 318	PLANAR MULTIBODY DYNAMICS AND SIMULATION (Programme Elective - II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the kinematics and dynamics of multibody mechanical systems.
- Develop mathematical models using body, joint and point coordinate formulations.
- Analyze constrained mechanical systems using numerical techniques.
- Study contact, impact and friction phenomena in multibody systems
- Apply multibody dynamics principles to robotic systems, vehicles and autonomous machines.

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

1. Model planar multibody systems using kinematic and dynamic principles.
2. Develop equations of motion using body, joint and point coordinate formulations.
3. Analyze constrained systems using numerical simulation techniques.
4. Evaluate contact, impact and friction effects in mechanical systems.
5. Apply multibody dynamics tools to robotic, vehicular and autonomous engineering applications.

UNIT – I Introduction to Multibody Systems

Multibody mechanical systems, types of analyses, planar kinematics and dynamics, rigid body motion, degrees of freedom, generalized coordinates, constraint equations, kinematic joints, applied forces, reaction forces, work and energy principles, equations of motion, modeling of mechanical and robotic systems.

UNIT – II Kinematic Analysis and Dynamic Modeling

Open-chain and closed-chain mechanisms, vector kinematics, slider-crank mechanisms, four-bar mechanisms, robotic linkages, free-body diagrams, force analysis, dynamic force analysis, generalized coordinates, Jacobian matrices, velocity and acceleration analysis, applications to robotic manipulators and vehicle mechanisms.

UNIT – III Coordinate Formulations for Multibody Systems

Body-coordinate formulation, joint-coordinate formulation and point-coordinate formulation, revolute and translational joints, system constraints, Lagrange multipliers, constrained equations of motion, recursive kinematics, introduction to Recursive Newton–Euler formulation, system Jacobian, numerical implementation of multibody formulations.

UNIT – IV Contact, Impact and Numerical Simulation

Contact modeling, collision detection, impact dynamics, momentum methods, friction models, constrained and unconstrained impacts, numerical integration methods, Euler and Runge–Kutta methods, simulation of multibody systems using computational tools.

UNIT – V Applications of Multibody Dynamics

Inverse dynamics and forward dynamics, robotic manipulators, mobile robots, vehicle suspension systems, autonomous ground vehicles, exoskeletons, biomechanical systems, digital twins of mechanical systems, multibody simulation software (MATLAB/Simscape, MSC ADAMS, RecurDyn), industrial applications and emerging trends in multibody system analysis.

Software / Tools Required

MATLAB & Simulink (Simscape Multibody), MSC ADAMS, RecurDyn, Python (NumPy, SciPy, Matplotlib), Simulink, SolidWorks Motion, ANSYS Motion, Autodesk Inventor Dynamic Simulation, ROS2 (for robotic multibody applications), CoppeliaSim (V-REP), Git & GitHub

Illustrative Case Studies

- Dynamic analysis of a four-bar linkage mechanism
- Simulation of a slider-crank mechanism
- Multibody dynamics of robotic manipulators
- Vehicle suspension system modeling and simulation
- Dynamic modeling of mobile robots
- Contact and impact analysis in robotic systems
- Exoskeleton dynamics and human motion simulation
- Digital twin development of a robotic mechanism

NPTEL / SWAYAM Online Resources

- nptel.ac.in/courses/112108313 (Dynamic control of mechanical system IISc Bangalore)
- nptel.ac.in/courses/112107214 (Modelling And Simulation Of Dynamic Systems, IIT Roorkee)

Professional Resources

- MSC ADAMS Documentation
- RecurDyn Documentation
- MATLAB Simscape Multibody Documentation
- ANSYS Motion Documentation
- SolidWorks Motion Documentation
- ROS2 Official Documentation
- Springer Handbook of Robotics
- ASME Digital Collection
- IEEE Robotics and Automation Society
- GitHub Multibody Dynamics Projects

Suggested Learning Activities

- Model and simulate planar multibody systems using MATLAB Simscape Multibody.
- Analyze kinematics and dynamics of four-bar and slider-crank mechanisms.
- Develop equations of motion using body, joint, and point coordinate formulations.
- Simulate robotic manipulators using MSC ADAMS or RecurDyn.
- Perform contact and impact analysis of multibody systems.

- Implement numerical integration methods (Euler and Runge–Kutta) for dynamic simulation.
- Study vehicle suspension and mobile robot dynamics through simulation.
- Develop a digital twin of a multibody mechanical system.
- Review IEEE/ASME research papers on multibody dynamics and robotic applications.
- Complete a mini-project on modeling and simulation of a robotic manipulator or vehicle suspension system using multibody dynamics software.

Suggested Text Books

1. Parviz E. Nikravesh, *Planar Multibody Dynamics: Formulation, Programming and Applications*, CRC Press, 2008.
2. Ahmed A. Shabana, *Computational Dynamics*, 3rd Edition, Wiley, 2010.
3. Ahmed A. Shabana, *Dynamics of Multibody Systems*, 4th Edition, Cambridge University Press, 2013.
4. Olivier A. Bauchau and Jacques Rodriguez, *Flexible Multibody Dynamics*, Springer, 2011.
5. R. E. Roberson and R. Schwertassek, *Dynamics of Multibody Systems*, Springer, 1988.
6. H. Chaudhary and S. K. Saha, *Dynamics and Balancing of Multibody Systems*, Springer, 2007.
7. Jason K. Moore, *Human Control of Dynamical Systems*, Springer, 2024.
8. Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, 2nd Edition, Wiley, 2020.
9. MSC Software Corporation, *MSC ADAMS User Guide*, Latest Online Edition.
10. MathWorks, *Simscape Multibody Documentation*, Latest Online Edition.

Course Code ME 319	UAV DESIGN, FLIGHT DYNAMICS AND AUTONOMOUS AERIAL SYSTEMS (Programme Elective - II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the architecture, design principles and operational characteristics of Unmanned Aerial Vehicles (UAVs).
- Develop mathematical models and analyze the flight dynamics of multirotor and fixed-wing aerial systems.
- Study sensors, actuators, flight controllers and communication systems used in autonomous drones.
- Understand flight control, mission management and onboard autonomy for aerial robotic systems.
- Apply UAV technologies to inspection, agriculture, logistics, surveillance and intelligent transportation applications.

Course Outcomes

After completion of the course, students will be able to:

1. Classify UAV platforms and identify their subsystems and operational characteristics.
2. Analyze the kinematics, aerodynamics and dynamics of aerial robotic systems.
3. Design and evaluate flight control systems for autonomous UAV operation.
4. Develop mission planning and onboard autonomy solutions using modern UAV platforms.
5. Apply UAV technologies to industrial, agricultural, inspection and surveillance applications.

UNIT – I Fundamentals of UAV Systems

Introduction to aerial robotics, evolution of UAV technology, classification of UAVs, fixed-wing aircraft, rotary-wing aircraft, multirotors, hybrid VTOL systems, flapping-wing aerial robots, UAV architecture and subsystems, payload considerations, performance metrics, design requirements, applications of aerial robots in agriculture, logistics, inspection, surveillance, disaster management and smart cities.

UNIT – II Sensors, Actuators and Flight Control Hardware

UAV sensors including IMU, GPS, magnetometer, barometer, LiDAR, cameras and depth sensors, sensor characteristics and calibration, BLDC motors, ESCs, propellers, servo systems, power systems, batteries and energy management, flight controllers, PX4 and ArduPilot architectures, MAVLink communication protocol, onboard computing platforms, companion computers and ROS2-PX4 integration concepts.

UNIT – III Flight Dynamics and Control of UAVs

Coordinate frames and transformations, Euler angles and quaternions, rigid body kinematics, aerodynamic forces and moments, multirotor UAV dynamics, introduction to fixed-wing

flight dynamics, stability analysis, flight control architecture, PID control, cascaded control loops, LQR concepts, attitude stabilization, altitude control and trajectory tracking.

UNIT – IV Autonomous UAV Systems and Mission Management

Mission planning concepts, waypoint navigation, geofencing, return-to-home strategies, autonomous mission execution, sensor fusion concepts, GPS-denied flight principles, onboard autonomy, UAV communication systems, telemetry systems, ground control stations, companion computer architecture, health monitoring, fault detection and autonomous decision-making concepts for UAV systems.

UNIT – V UAV Applications and Emerging Technologies

Precision agriculture, aerial inspection and monitoring, infrastructure inspection, aerial mapping and photogrammetry, search and rescue operations, drone delivery systems, swarm drones and cooperative UAV systems, human-drone interaction, edge AI for UAVs, digital twins for UAV fleets, urban air mobility (UAM), eVTOL systems, UAV regulations and safety standards, future trends in aerial robotics and autonomous aerial systems.

Software / Tools Required

PX4 Autopilot, ArduPilot, QGroundControl, Mission Planner, ROS2, Gazebo, MATLAB & Simulink, Python (DroneKit, OpenCV), AirSim (Microsoft), Blender, SolidWorks, Autodesk Fusion 360, NVIDIA Isaac Sim

Illustrative Case Studies

- Multicopter UAV for Aerial Mapping, UAV-Based Agricultural Monitoring System
- Drone-Based Infrastructure Inspection, Search and Rescue Mission Using UAVs
- Autonomous Delivery Drone System

NPTEL / SWAYAM Online Resources

- Unmanned Aerial Vehicles and Systems — <https://nptel.ac.in/courses/106105186>
- Introduction to Robotics — <https://nptel.ac.in/courses/112101099>
- Control Engineering — <https://nptel.ac.in/courses/108102044>

Professional Resource

- [PX4 Autopilot](#), [ArduPilot](#), [Dronecode Foundation](#), [QGroundControl](#), [NASA UAV Research](#), [DJI Developer](#)

Suggested Learning Activities (Any Five)

- UAV Flight Simulation and Control Tuning
- Mission Planning Using Ground Control Station
- Sensor Fusion and State Estimation Experiment
- Path Planning for Autonomous Drones

Suggested Text Books

1. Randal W. Beard and Timothy W. McLain, *Small Unmanned Aircraft: Theory and Practice*, 2nd Edition, Princeton University Press, 2024.

2. Kenzo Nonami, Farid Kendoul, Satoshi Suzuki, Wei Wang, and Daisuke Nakazawa, *Autonomous Flying Robots: Unmanned Aerial Vehicles and Micro Aerial Vehicles*, Springer, 2010.
3. Yasmina Bestaoui Sebbane, *Planning and Decision Making for Aerial Robots*, Springer, 2014.
4. Rafael Yanushevsky, *Modern Missile Guidance*, 2nd Edition, CRC Press, 2018.
5. Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd Edition, MIT Press, 2011.
6. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
7. Reg Austin, *Unmanned Aircraft Systems: UAV Design, Development and Deployment*, Wiley, 2010.
8. Paul G. Fahlstrom and Thomas J. Gleason, *Introduction to UAV Systems*, 5th Edition, Wiley, 2024.
9. George M. Siouris, *Missile Guidance and Control Systems*, Springer, 2004.
10. PX4 Development Team, *PX4 User Guide and Developer Documentation*, Latest Online Edition.
11. ArduPilot Development Team, *ArduPilot Documentation*, Latest Online Edition.
12. Luis Mejias, Antonios Tsourdos, Benjamín Barrientos, and others (Eds.), *Aerial Robotic Systems: Physically Interacting with the Environment*, Springer, 2017.

Course Code ME 320	INDUSTRIAL AUTOMATION AND PLC SYSTEMS (Programme Elective -II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the architecture of industrial automation systems.
- Learn PLC programming and industrial control strategies.
- Develop automation solutions using sensors, actuators and communication networks.
- Understand HMI, SCADA and distributed automation systems.
- Apply Industry 4.0 concepts in smart manufacturing environments.

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

1. Explain the architecture and operation of industrial automation systems.
2. Design and implement PLC-based automation solutions.
3. Develop HMI and SCADA systems for industrial monitoring and supervisory control.
4. Analyze industrial communication protocols and networked automation systems.
5. Integrate PLCs, industrial robots and Industry 4.0 technologies for smart manufacturing applications.

UNIT – I Fundamentals of Industrial Automation

Introduction to industrial automation, automation hierarchy, fixed, programmable and flexible automation, automation pyramid, sensors and actuators used in industrial automation, industrial control architectures, relay logic systems, comparison of relay-based and PLC-based control systems, industrial automation standards, automation in manufacturing industries and smart factories.

UNIT – II PLC Programming and Industrial Control

PLC architecture, CPU, memory organization, input-output modules, scan cycle, IEC 61131-3 standards, PLC programming software, Ladder Logic (LD), Function Block Diagram (FBD), Structured Text (ST), Sequential Function Charts (SFC), timers, counters, arithmetic and data handling instructions, sequential control systems, troubleshooting and industrial case studies.

UNIT – III Human Machine Interface and SCADA Systems

Human Machine Interface (HMI) architecture, graphical interface design, alarms and event management, data acquisition systems, SCADA architecture and components, real-time monitoring and control, industrial visualization, historical data logging, dashboards, reporting systems and supervisory control applications.

UNIT – IV Industrial Communication and Industrial IoT

Industrial communication fundamentals, Modbus, PROFIBUS, PROFINET, CANopen, EtherCAT, Ethernet/IP, OPC-UA architecture, MQTT protocol, industrial wireless

communication systems, Industrial Internet of Things (IIoT), cybersecurity in industrial automation, network reliability and communication case studies.

UNIT – V Smart Manufacturing and Advanced Industrial Automation

Industrial robotics integration with PLC systems, automation cells and flexible manufacturing systems, collaborative robots (Cobots), machine vision systems, automated inspection, predictive maintenance, cyber-physical systems, digital twins, cloud-based manufacturing, Industry 4.0 architecture, autonomous manufacturing systems and emerging trends in smart factories.

Software / Tools Required

Siemens TIA Portal, Rockwell Studio 5000, Allen-Bradley RSLogix, CODESYS, Factory I/O, Ignition SCADA, WinCC, AVEVA Edge (Wonderware), MATLAB & Simulink, Python (Pylogix, Snap7), Node-RED, Kepware OPC UA Server, MQTT Broker (Mosquitto), LabVIEW, Arduino IDE

Illustrative Case Studies

- PLC-Based Conveyor Automation System, SCADA-Based Industrial Monitoring System, Smart Factory Automation Using Industry 4.0, Machine Vision-Based Quality Inspection System, Industrial Robot Integration with PLC Control

NPTEL / SWAYAM Online Resources

1. Industrial Automation and Control — <https://nptel.ac.in/courses/108105088>
2. Programmable Logic Controllers and SCADA Systems <https://nptel.ac.in/courses/108105088>
3. Industrial Internet of Things and Smart Manufacturing — <https://nptel.ac.in/courses/106105195>

Professional Resources

- [Siemens Industry Automation](#), [Rockwell Automation](#), [International Society of Automation](#), [OPC Foundation](#), [EtherCAT Technology Group](#), [Modbus Organization](#)

Suggested Learning Activities

- PLC Ladder Logic Programming Exercises
- SCADA System Design and Simulation
- Industrial Communication Protocol Testing
- HMI Screen Design Project

Suggested Text Books

1. Frank D. Petruzella, *Programmable Logic Controllers*, 5th Edition, McGraw-Hill Education, 2021.
2. John W. Webb and Ronald A. Reis, *Programmable Logic Controllers: Principles and Applications*, 6th Edition, Pearson, 2003.
3. Hugh Jack, *Automating Manufacturing Systems with PLCs*, Version 6.0, 2020.
4. Mikell P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, 5th Edition, Pearson, 2020.
5. B. R. Mehta and Y. J. Reddy, *Industrial Process Automation Systems: Design and Implementation*, Elsevier, 2015.
6. Richard Zurawski (Ed.), *Industrial Communication Technology Handbook*, 2nd Edition, CRC Press, 2015.
7. Gary Dunning, *Introduction to Programmable Logic Controllers*, 4th Edition, Cengage Learning, 2013.
8. Alasdair Gilchrist, *Industry 4.0: The Industrial Internet of Things*, Apress, 2016.
9. Krishna Kant, *Computer-Based Industrial Control*, 2nd Edition, Prentice Hall of India, 2009.

Course Code ME 321	EVOLUTIONARY COMPUTATION FOR ROBOTICS AND AUTONOMOUS SYSTEMS (Program Elective – II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the mathematical foundations and formulation of optimization problems.
- Learn classical and modern optimization techniques used in engineering and robotics.
- Develop optimization models for robot design, motion planning and control.
- Apply evolutionary and swarm intelligence algorithms for engineering applications.
- Utilize optimization methods for intelligent systems, machine learning and autonomous robots.

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

1. Formulate optimization problems involving engineering design and robotic systems.
2. Apply unconstrained and constrained optimization techniques to solve engineering problems.
3. Utilize evolutionary and swarm intelligence algorithms for single and multi-objective optimization.
4. Analyze and optimize robotic motion, trajectory and control problems.
5. Apply optimization techniques in robotics, machine learning, autonomous systems and smart manufacturing.

UNIT – I: Foundations of Evolutionary Computation

Introduction to computational intelligence and evolutionary computation, optimization problems in robotics and engineering, search spaces, fitness landscapes, representation schemes, population-based search, selection mechanisms, exploration and exploitation, fitness evaluation, constraint handling techniques, applications of evolutionary computation in robotics and autonomous systems.

UNIT – II: Evolutionary Algorithms

Genetic Algorithms (GA), chromosome encoding, fitness functions, selection methods, crossover and mutation operators, Evolution Strategies (ES), Evolutionary Programming (EP), Differential Evolution (DE), adaptive evolutionary algorithms, constraint handling, multi-objective optimization, Pareto optimality, NSGA-II and SPEA2, engineering optimization applications.

UNIT – III: Swarm Intelligence and Nature-Inspired Algorithms

Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), Grey Wolf Optimizer (GWO), Whale Optimization Algorithm (WOA), Firefly Algorithm (FA), Bat Algorithm (BA), parameter tuning, convergence analysis, comparative performance of swarm intelligence algorithms.

UNIT – IV: Evolutionary Robotics

Robot design optimization, manipulator parameter optimization, robot trajectory optimization, inverse kinematics using evolutionary algorithms, mobile robot path planning,

autonomous navigation, multi-robot task allocation, UAV/drone path planning, obstacle avoidance, reinforcement learning with evolutionary algorithms, hyperparameter optimization.

UNIT – V: Emerging Applications of Evolutionary Computation

Neuroevolution, evolutionary reinforcement learning, neural architecture search, evolutionary optimization for digital twins, Industry 4.0 and smart manufacturing, topology optimization, autonomous vehicles, human–robot collaboration, soft robotics, multi-agent systems, recent advances and future trends.

Software / Tools Required

MATLAB & Simulink (Global Optimization Toolbox), Python (NumPy, SciPy, DEAP, PyGAD, PySwarms, Matplotlib), Jupyter Notebook/Google Colab, ROS 2, Gazebo, MoveIt 2, OpenAI Gym/Gymnasium, Stable-Baselines3, Robot Operating System (ROS), Git & GitHub.

Illustrative Case Studies

- Robot trajectory optimization using Genetic Algorithms.
- Mobile robot path planning using Particle Swarm Optimization.
- Manipulator parameter optimization using Differential Evolution.
- Multi-objective robot design using NSGA-II.
- Drone path planning using Ant Colony Optimization.
- Reinforcement learning with evolutionary strategies for autonomous navigation.
- Hyperparameter optimization of robotic perception models.
- Topology optimization of lightweight robotic components.
- Multi-robot task allocation using swarm intelligence.
- Autonomous warehouse robot routing using bio-inspired optimization.

NPTEL / SWAYAM Online Resources

1. Intelligent Control of Robotic Systems – IIT Roorkee.
2. Industrial Robotics – IIT (ISM) Dhanbad.
3. Artificial Intelligence: Search Methods for Problem Solving – IIT Madras.
4. Introduction to Machine Learning – IIT Madras.
5. Introduction to Robotics – IIT Roorkee. Professional Resources

Suggested Learning Activities

- Implement Genetic Algorithms for engineering optimization.
- Develop Differential Evolution algorithms using Python.
- Solve optimization problems using PSO, ACO, GWO and WOA.
- Optimize robot trajectories and manipulator parameters.
- Develop multi-objective optimization solutions using NSGA-II.
- Implement swarm intelligence algorithms for autonomous navigation.
- Apply evolutionary algorithms for reinforcement learning.
- Optimize machine learning hyperparameters using evolutionary computation.
- Review IEEE papers on evolutionary robotics.
- Complete a mini-project on autonomous robot optimization.

Suggested Text Books

1. Kenneth A. De Jong, *Evolutionary Computation: A Unified Approach*, MIT Press, 2016.
2. Mykel J. Kochenderfer and Tim A. Wheeler, *Algorithms for Optimization*, MIT Press, 2019.
3. A. E. Eiben and J. E. Smith, *Introduction to Evolutionary Computing*, 2nd Edition, Springer, 2015.
4. Kalyanmoy Deb, *Multi-Objective Optimization Using Evolutionary Algorithms*, Wiley, 2001.
5. David E. Goldberg, *Genetic Algorithms in Search, Optimization and Machine Learning*, Addison-Wesley, 1989.
6. Xin-She Yang, *Nature-Inspired Optimization Algorithms*, 2nd Edition, Elsevier, 2021.
7. Andries P. Engelbrecht, *Computational Intelligence: An Introduction*, 2nd Edition, Wiley, 2007.
8. Carlos A. Coello Coello, Gary B. Lamont, and David A. Van Veldhuizen, *Evolutionary Algorithms for Solving Multi-Objective Problems*, 2nd Edition, Springer, 2007.

Course Code ME 322	SMART MATERIALS AND SOFT ROBOTICS (Programme Elective - III)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the principles of smart materials used in sensing, actuation and intelligent robotic systems.
- Analyze the behavior and performance characteristics of smart material-based actuators and sensors.
- Study soft robotic structures, soft actuators and compliant robotic mechanisms.
- Develop smart material-based systems for wearable robots, rehabilitation devices and bio-inspired robots.
- Apply smart materials and soft robotics technologies to emerging engineering and biomedical applications.

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

1. Classify and characterize smart materials used in sensing and actuation applications.
2. Analyze the behavior and performance of smart material-based actuators and sensors.
3. Design smart actuation systems using SMA, piezoelectric, electroactive polymer and soft actuator technologies.
4. Develop soft robotic mechanisms and compliant robotic systems.
5. Apply smart materials and soft robotics concepts to wearable robots, rehabilitation devices and bio-inspired robotic systems.

UNIT – I Introduction to Smart Materials and Intelligent Actuation

Introduction to smart materials and intelligent systems, characteristics of smart materials, sensing and actuation principles, smart structures, smart sensors and actuators, piezoelectric materials, piezoelectric effect, piezoelectric ceramics and polymers, piezoelectric sensors and actuators, vibration control, precision positioning systems, applications in robotics, aerospace and biomedical systems.

UNIT – II Shape Memory Materials and Smart Actuators

Shape Memory Alloys (SMA), shape memory effect, pseudoelasticity, phase transformation mechanisms, constitutive behavior of SMA, SMA wires, springs and actuators, actuator design considerations, control of SMA actuators, applications in robotic grippers, wearable devices, rehabilitation robotics, robotic gloves, aerospace systems and biomedical devices.

UNIT – III Electroactive Polymers and Soft Actuation Systems

Electroactive Polymers (EAPs), Ionic Polymer Metal Composites (IPMC), dielectric elastomers, conductive polymers, carbon nanotube-based actuators, artificial muscles, soft actuator design principles, performance characteristics, control challenges in soft actuators, tactile systems, soft sensing concepts, biomimetic actuation and medical device applications.

UNIT – IV Soft Robotics Design and Control

Introduction to soft robotics, compliant mechanisms, soft robotic structures, soft robotic manipulators, continuum robots, pneumatic soft actuators, fluidic elastomer actuators, soft grippers, bio-inspired soft robotic systems, modeling challenges, sensing and control of soft robots, embedded sensing technologies, human-safe robotic interaction and soft robotic locomotion.

UNIT – V Wearable Robotics and Emerging Applications

Smart material-based robotic systems, wearable robotics, upper-limb and lower-limb exoskeletons, rehabilitation devices, assistive robotic systems, robotic prostheses, soft wearable robots, human augmentation systems, bio-inspired robotic actuators, smart manufacturing applications, micro-electromechanical systems (MEMS), energy harvesting systems, recent advances and future trends in smart materials and soft robotics.

Software / Tools Required

MATLAB & Simulink, ANSYS (Mechanical/Multiphysics), COMSOL Multiphysics, ABAQUS, SolidWorks, Autodesk Fusion 360, OpenSim, Python (NumPy, SciPy, PyTorch), LabVIEW, Adams MSC, ROS

Illustrative Case Studies

- Piezoelectric Actuator-Based Precision Positioning System
- Shape Memory Alloy (SMA) Based Robotic Gripper
- Electroactive Polymer-Based Artificial Muscle System
- Soft Robotic Gripper for Delicate Object Handling
- Wearable Exoskeleton for Rehabilitation Assistance

NPTEL / SWAYAM Online Resources

- Smart Materials and Structures — <https://nptel.ac.in/courses/112104251>
- Smart Materials and Systems — <https://nptel.ac.in/courses/113105098>
- Soft Robotics — <https://nptel.ac.in/courses/112105299>

Professional Resources

- [IEEE Robotics and Automation Society](#)
- [ASME Smart Materials Division](#)
- [SPIE Smart Structures](#)
- [COMSOL Smart Materials Resources](#)
- [Smart Materials and Structures Journal \(IOP\)](#)

Suggested Learning Activities

- SMA Actuator Characterization Experiment, Piezoelectric Sensor Signal Analysis
- Soft Robotic Gripper Design Project, Electroactive Polymer Simulation Study
- Smart Material-Based Motion Control Simulation, Wearable Robotics Case Study Analysis, Mini Project on Bio-Inspired Soft Robotics

Suggested Text Books

1. José L. Pons, *Emerging Actuator Technologies: A Micromechatronic Approach*, John Wiley & Sons, 2005.

2. Ralph C. Smith, ***Smart Material Systems: Model Development***, Society for Industrial and Applied Mathematics (SIAM), 2005.
3. Yoseph Bar-Cohen (Ed.), ***Electroactive Polymer (EAP) Actuators as Artificial Muscles: Reality, Potential, and Challenges***, 2nd Edition, SPIE Press, 2004.
4. Cecilia Laschi, Barbara Mazzolai, and Matteo Cianchetti, ***Soft Robotics: Trends, Applications and Challenges***, Springer, 2016.
5. Srinivasan Aluru (Ed.), ***Smart Materials and Structures***, Springer, 2020.
6. Vijay K. Varadan, K. J. Vinoy, and S. Gopalakrishnan, ***Smart Material Systems and MEMS: Design and Development Methodologies***, John Wiley & Sons, 2006.
7. Kinji Asaka and Zhongkui Wang (Eds.), ***Ionic Polymer Metal Composites (IPMCs): Fundamentals and Applications***, Springer, 2011.
8. Federico Carpi, Danilo De Rossi, Roy Kornbluh, Ronald Pelrine, and Paolo Sommer-Larsen (Eds.), ***Dielectric Elastomers as Electromechanical Transducers: Fundamentals, Materials, Devices, Models and Applications of an Emerging Electroactive Polymer Technology***, Elsevier, 2011.
9. Bruno Siciliano and Oussama Khatib (Eds.), ***Springer Handbook of Robotics***, 2nd Edition, Springer, 2016.

Course Code ME 323	INTELLIGENT MOBILE ROBOTS AND AUTONOMOUS SYSTEMS (Programme Elective - III)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the architecture, locomotion mechanisms and operational principles of intelligent mobile robots.
- Develop kinematic models and motion control strategies for autonomous mobile robotic platforms.
- Study sensing, perception and software architectures used in intelligent mobile robots.
- Analyze autonomous decision-making, fleet management and mobile manipulation systems.
- Apply intelligent mobile robots in industrial, service, agricultural and autonomous transportation applications.

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

1. Classify mobile robot platforms and analyze their locomotion and mobility characteristics.
2. Develop kinematic models and motion control strategies for autonomous mobile robots.
3. Design sensing and software architectures for intelligent robotic systems.
4. Analyze autonomous operation, fleet coordination and mobile manipulation systems.
5. Apply intelligent mobile robots in industrial, service and autonomous transportation applications.

UNIT – I Mobile Robot Platforms and Locomotion Systems

Introduction to intelligent mobile robots, classification of mobile robotic systems, wheeled, tracked, legged and hybrid mobile robots, differential drive robots, skid-steer robots, omnidirectional robots, Ackermann steering vehicles, autonomous guided vehicles (AGVs), autonomous mobile robots (AMRs), mobility and maneuverability analysis, performance measures, applications in logistics, healthcare, agriculture, surveillance and service robotics.

UNIT – II Mobile Robot Modeling and Motion Control

Coordinate frames and transformations, kinematic modeling of differential drive, omnidirectional and car-like robots, wheel odometry, motion control fundamentals, trajectory tracking, path following, feedback control strategies, PID-based motion control, velocity control, stability considerations, mobile robot control architectures and practical implementation issues.

UNIT – III Mobile Robot Sensing and Software Architecture

Sensors used in mobile robots, wheel encoders, IMU, LiDAR, ultrasonic sensors, RGB and RGB-D cameras, force and proximity sensors, sensor integration concepts, embedded

controllers, onboard computing systems, robot software architecture, Robot Operating System (ROS2), Navigation2 (Nav2) framework overview, communication architecture, middleware and software integration for autonomous robots.

UNIT – IV Autonomous Mobile Robot Systems

Autonomous robot operation, task execution frameworks, behavior-based robotics, decision-making architectures, finite state machines, behavior trees, autonomous warehouse robots, fleet management systems, robot scheduling, human-aware robot operation, safety systems, collaborative mobile robots, autonomous delivery systems and mobile manipulation concepts.

UNIT – V Industrial Applications and Emerging Trends

Industrial AMRs, autonomous forklifts, warehouse automation systems, agricultural mobile robots, inspection and maintenance robots, healthcare and service robots, cleaning robots, autonomous transportation systems, Internet of Robotic Things (IoRT), edge AI for mobile robots, digital twins for robotic systems, swarm-enabled mobile robot applications, future trends in intelligent autonomous systems.

Software / Tools Required

ROS2, Gazebo, RViz, Navigation2 (Nav2), MoveIt, Python (NumPy, OpenCV, SciPy), MATLAB & Simulink, C++, Ignition Gazebo, NVIDIA Isaac Sim, Webots, SolidWorks, Autodesk Fusion 360, Docker

Illustrative Case Studies

- Autonomous Warehouse Mobile Robot System
- Differential Drive Robot Path Tracking
- Autonomous Delivery Robot for Service Applications
- AGV-Based Industrial Material Handling System
- LiDAR-Based Navigation and Mapping Robot

NPTEL / SWAYAM Online Resources

1. Introduction to Robotics — <https://nptel.ac.in/courses/112101099>
2. Mobile Robotics — <https://nptel.ac.in/courses/112105304>
3. Robot Motion Planning — <https://nptel.ac.in/courses/112106298>

Professional Resources

- [ROS 2 Documentation](#)
- [Open Robotics](#)
- Nav2 Framework
- [Clearpath Robotics](#)
- [Fetch Robotics](#)
- [IEEE Robotics and Automation Society](#)

Suggested Learning Activities

- Mobile Robot Kinematics Simulation
- Path Planning and Obstacle Avoidance Project
- LiDAR-Based Mapping Exercise

- ROS2 Navigation Stack Implementation
- Differential Drive Robot Control Experiment
- Warehouse Robot Simulation Case Study
- Mini Project on Autonomous Delivery Robots

Suggested Text Books

1. Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd Edition, MIT Press, 2011.
2. Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017.
3. Peter Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB®*, 2nd Edition, Springer, 2017.
4. Alonzo Kelly, *Mobile Robotics: Mathematics, Models, and Methods*, Cambridge University Press, 2013.
5. Sebastian Thrun, Wolfram Burgard, and Dieter Fox, *Probabilistic Robotics*, MIT Press, 2005.
6. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
7. Anis Koubaa (Ed.), *Robot Operating System (ROS): The Complete Reference*, Volume 1, Springer, 2016.
8. Robin R. Murphy, *Introduction to AI Robotics*, 2nd Edition, MIT Press, 2019.
9. Maja J. Matarić, *The Robotics Primer*, 2nd Edition, MIT Press, 2017.

Course Code ME 324	REINFORCEMENT LEARNING FOR ROBOTICS AND AUTONOMOUS SYSTEMS (Programme Elective - III)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-		40	60	

Course Objectives

- Understand the fundamentals of reinforcement learning and sequential decision-making.
- Learn mathematical foundations of Markov Decision Processes (MDPs) and dynamic programming.
- Develop model-free and model-based reinforcement learning algorithms.
- Understand deep reinforcement learning techniques for autonomous systems.
- Apply reinforcement learning to robotics, autonomous navigation, control, and intelligent decision-making.

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

1. Formulate engineering problems using reinforcement learning frameworks.
2. Develop and analyze value-based and policy-based reinforcement learning algorithms.
3. Apply reinforcement learning techniques to autonomous decision-making systems.
4. Design deep reinforcement learning solutions for robotic control and navigation problems.
5. Implement reinforcement learning algorithms for robotics, autonomous vehicles, drones, and industrial automation applications.

UNIT – I Fundamentals of Reinforcement Learning

Introduction to reinforcement learning, agent-environment interaction, sequential decision making, Markov property, Markov Reward Processes, Markov Decision Processes (MDPs), state space, action space, reward functions, policies, value functions, Bellman equations, exploration versus exploitation, applications in robotics and autonomous systems.

UNIT – II Dynamic Programming and Model-Based Reinforcement Learning

Policy evaluation, policy improvement, policy iteration, value iteration, generalized policy iteration, dynamic programming algorithms, model-based reinforcement learning, planning under uncertainty, computational challenges and limitations of dynamic programming.

UNIT – III Model-Free Reinforcement Learning

Monte Carlo methods, temporal difference learning, SARSA algorithm, Q-learning, Expected SARSA, eligibility traces, exploration strategies, ϵ -greedy methods, softmax exploration, comparison of value-based learning algorithms, applications in autonomous decision making.

UNIT – IV Deep Reinforcement Learning

Introduction to deep reinforcement learning, Deep Q Networks (DQN), experience replay, target networks, Double DQN, policy gradient methods, REINFORCE algorithm, actor-critic

architecture, Advantage Actor-Critic (A2C), Proximal Policy Optimization (PPO), Soft Actor-Critic (SAC), continuous control problems.

UNIT – V Applications in Robotics and Autonomous Systems

Reinforcement learning for robot navigation, mobile robot path planning, obstacle avoidance, robot manipulation and grasping, reinforcement learning for UAVs and autonomous vehicles, multi-agent reinforcement learning, sim-to-real transfer, reinforcement learning in smart manufacturing, industrial automation, embodied AI and emerging trends in robot learning.

Software / Tools Required

- Python (NumPy, SciPy, Gymnasium, Stable-Baselines3), PyTorch, TensorFlow, JAX, MATLAB & Simulink, ROS2, Gazebo, Isaac Gym, NVIDIA Isaac Sim, OpenAI Gym, MuJoCo, Webots, Unity ML-Agents, Docker, Kubernetes

Illustrative Case Studies

- Deep Q-Learning for Obstacle Avoidance
- Robot Arm Manipulation Using Reinforcement Learning
- UAV Path Planning Using PPO Algorithm
- Multi-Agent Reinforcement Learning for Swarm Robots

NPTEL / SWAYAM Online Resources

1. Reinforcement Learning — <https://nptel.ac.in/courses/106106143>
2. Machine Learning — <https://nptel.ac.in/courses/106106139>
3. Deep Learning — <https://nptel.ac.in/courses/106106184>

Professional Resources

1. [OpenAI Spinning Up in Deep RL](#), [DeepMind Research](#), [PyTorch RL Library](#)
2. [TensorFlow Agents](#), [OpenAI Gym Documentation](#), [Stable-Baselines3 Docs](#)
3. [IEEE Robotics and Automation Society](#)

Suggested Learning Activities

- Implement Q-Learning for Grid World Navigation
- Train DQN for Robot Path Planning
- Simulate Robot Arm Control Using RL
- Compare SARSA vs Q-Learning Performance
- PPO-Based Drone Control Simulation
- Multi-Agent RL Simulation Exercise
- Mini Project on RL for Autonomous Systems

Suggested Text Books

1. **Richard S. Sutton** and **Andrew G. Barto**, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, 2018.
2. **Csaba Szepesvári**, *Algorithms for Reinforcement Learning*, Morgan & Claypool Publishers, 2010.
3. **Maxim Lapan**, *Deep Reinforcement Learning Hands-On*, 3rd Edition, Packt Publishing, 2024. (Use the latest available edition.)
4. **Laura Graesser** and **Wah Loon Keng**, *Foundations of Deep Reinforcement Learning: Theory and Practice in Python*, 2nd Edition, Addison-Wesley Professional, 2022.
5. **Stuart J. Russell** and **Peter Norvig**, *Artificial Intelligence: A Modern Approach*, 4th Edition, Pearson, 2021.
6. **Ian Goodfellow**, **Yoshua Bengio**, and **Aaron Courville**, *Deep Learning*, MIT Press, 2016.
7. **Sebastian Thrun**, **Wolfram Burgard**, and **Dieter Fox**, *Probabilistic Robotics*, MIT Press,

Course Code ME 325	HUMAN-ROBOT INTERACTION AND COLLABORATIVE ROBOTICS (Programme Elective - III)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the principles and challenges of Human-Robot Interaction (HRI).
- Learn methods for communication and collaboration between humans and robots.
- Study human factors, cognition, ergonomics and safety in robotic systems.
- Develop intelligent human-aware robotic systems.
- Apply HRI concepts in collaborative robots, service robots and assistive technologies.

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

1. Explain the fundamentals and applications of Human-Robot Interaction.
2. Analyze human factors, ergonomics and cognitive aspects in robotic systems.
3. Design human-robot communication and interaction frameworks.
4. Develop collaborative robotic systems with safety and reliability considerations.
5. Apply AI and perception techniques for intelligent human-aware robots.

UNIT – I Fundamentals of Human–Robot Interaction

Introduction to Human-Robot Interaction, evolution of HRI, human-centered robotics, applications of HRI in industry, healthcare, rehabilitation, education and service sectors, classifications of interaction, levels of robot autonomy, human-in-the-loop systems, challenges and future trends in HRI.

UNIT – II Human Factors and Human-Centered Design

Human perception and cognition, human decision-making process, ergonomics in robotics, anthropometry, workload analysis, cognitive workload assessment, situation awareness, usability engineering, user experience design, trust in robotic systems, acceptance of robots, social and ethical issues in HRI, standards and guidelines for human-centered robot design.

UNIT – III Human–Robot Communication and Interaction Modalities

Verbal and non-verbal communication, speech recognition and synthesis, gesture recognition, facial expression recognition, eye gaze tracking, haptic interaction, multimodal interaction, introduction to natural language interaction, intention recognition, wearable sensing systems, interaction frameworks for collaborative robots.

UNIT – IV Collaborative Robotics and Shared Autonomy

Collaborative robots (Cobots), physical human-robot interaction, safety standards for collaborative robots (ISO 10218 and ISO/TS 15066), shared control architectures, human-aware motion planning, adaptive robot behavior, intention prediction, explainable human-robot collaboration, robot learning from demonstration, teleoperation and assistive robotics.

UNIT – V Intelligent Human–Robot Interaction Systems

Machine learning and AI in HRI, affective computing, emotion recognition, introduction to learning-based interaction, social robotics, assistive and rehabilitation robots, exoskeletons, humanoid robots, digital humans, autonomous service robots, ethical AI, explainable robotics and future trends in HRI.

Software / Tools Required

Python (OpenCV, NumPy, SciPy, MediaPipe, TensorFlow, PyTorch), ROS2, Gazebo, RViz, Unity 3D, NVIDIA Isaac Sim, MATLAB & Simulink, OpenFace, OpenSMILE, PyGaze, Webots, Blender, CoppeliaSim (V-REP), OpenAI APIs

Illustrative Case Studies

- Human–Robot Collaboration in Industrial Assembly
- Social Robot for Service Applications
- Teleoperated Robot for Remote Assistance
- Assistive Robot for Rehabilitation Tasks
- Emotion-Aware Human–Robot Interaction System

NPTEL / SWAYAM Online Resources

- Human–Robot Interaction — <https://nptel.ac.in/courses/112105297>
- Human-Centered Robotics — <https://nptel.ac.in/courses/112105298>
- Introduction to Robotics — <https://nptel.ac.in/courses/112101099>

Professional Resources

- [IEEE Robotics and Automation Society](#), [ACM SIGCHI \(Human–Computer Interaction\)](#), [ISO Robot Safety Standards](#), [OpenAI Research](#), [MIT CSAIL HRI Research](#), Stanford HRI Lab , [ROS Official Website](#)

Suggested Learning Activities

- Human–Robot Interaction Simulation in ROS2
- Gesture-Based Robot Control Project
- Speech-Based Robot Interaction System
- Collaborative Robot Safety Study
- Emotion Recognition Using AI Models
- Teleoperation Robot Control Experiment
- Mini Project on Social or Assistive Robotics

Suggested Text Books

1. Christoph Bartneck, Dana Kulić, Elizabeth Croft, and Susana Zoghbi, *Human-Robot Interaction: An Introduction*, Cambridge University Press, 2020.
2. Julie A. Adams, William A. Smart, and Holly A. Yanco, *Human-Robot Interaction, Foundations and Trends® in Human–Computer Interaction*, Now Publishers, 2014.
3. Dan Zhang and Bin Wei (Eds.), *Human-Robot Interaction and Collaboration*, Springer, 2020.
4. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
5. Maja J. Matarić, *The Robotics Primer*, 2nd Edition, MIT Press, 2017.
6. Robin R. Murphy, *Introduction to AI Robotics*, 2nd Edition, MIT Press, 2019.
7. Guy Hoffman, *Human-Robot Interaction*, Cambridge University Press, 2025.
8. Paolo Dario and Arianna Menciassi (Eds.), *Biomedical Robotics*, Springer, 2024.
9. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, 2018.

Course Code ME 326	VIBRATION ANALYSIS, CONDITION MONITORING AND PREDICTIVE MAINTENANCE (Programme Elective - III)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-		40	60	

Course Objectives

- Understand the fundamentals of vibration analysis in mechanical systems.
- Develop mathematical models for free and forced vibration systems.
- Analyze single and multi-degree-of-freedom systems using analytical and numerical methods.
- Study condition monitoring techniques for machinery health assessment.
- Apply modern predictive maintenance techniques using signal processing and intelligent monitoring systems.

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

1. Analyze vibration characteristics of mechanical systems under free and forced vibration conditions.
2. Develop mathematical models for SDOF and MDOF systems and determine their dynamic response.
3. Apply modal analysis and vibration control techniques to engineering systems.
4. Evaluate machine condition using vibration-based condition monitoring techniques.
5. Apply signal processing and predictive maintenance methods for intelligent machinery health monitoring.

UNIT – I Fundamentals of Mechanical Vibrations

Causes and effects of vibration, vibration terminology, single degree-of-freedom systems, free vibration, damped vibration, forced vibration, resonance, transmissibility, vibration response characteristics and engineering applications.

UNIT – II Two Degree-of-Freedom Systems and Vibration Control

Two degree-of-freedom systems, bending vibrations of two degree-of-freedom systems, natural frequencies and mode shapes, steady-state and transient vibration response, vibration absorbers, tuned mass dampers, vibration isolation techniques and practical applications.

UNIT – III Multi Degree-of-Freedom Systems and Modal Analysis

Multi degree-of-freedom systems, Dunkerley method, Rayleigh method, Holzer method, introduction to numerical vibration analysis, modal analysis, mode shapes, modal testing concepts, finite element-based vibration analysis, applications to machinery and structural systems.

UNIT – IV Condition Monitoring and Vibration Diagnostics

Introduction to condition monitoring, failure mechanisms and failure analysis, vibration measuring instruments, vibration transducers, signal conditioning elements, data acquisition systems, display and recording systems, vibration meters and analyzers, frequency spectrum

analysis, Fast Fourier Transform (FFT), time-domain and frequency-domain analysis, vibration standards, machine condition assessment through vibration monitoring.

UNIT – V Predictive Maintenance and Advanced Monitoring Techniques

Lubricant and contaminant analysis, Spectrometric Oil Analysis Program (SOAP), ultrasonic monitoring, shock pulse measurement, acoustic emission monitoring, cepstrum analysis, critical speed analysis, shaft orbit and position analysis, predictive maintenance strategies, machine learning applications in fault diagnosis, IoT-enabled condition monitoring systems, digital twins for machinery health monitoring and emerging trends in intelligent maintenance systems.

Software / Tools Required

MATLAB & Simulink, ANSYS Mechanical, Abaqus, MSC Nastran, LabVIEW, Python (NumPy, SciPy, Pandas, PyWavelets), Signal Processing Toolbox (MATLAB), NI DIAdem, COMSOL Multiphysics, SolidWorks Simulation, FFT Analyzer Software

Illustrative Case Studies

- Vibration Analysis of Rotating Machinery, Dynamic Response of Beam Structures
- Vibration Control Using Tuned Mass Damper, Condition Monitoring of Industrial Equipment, Predictive Maintenance Using Vibration Signals

NPTEL / SWAYAM Online Resources

1. Mechanical Vibrations — <https://nptel.ac.in/courses/112105268>
2. Condition Monitoring and Predictive Maintenance — <https://nptel.ac.in/courses/112105308>
3. Engineering Mechanics and Vibrations — <https://nptel.ac.in/courses/112105297>

Professional Resources

- [Society for Experimental Mechanics \(SEM\)](#), [ASME Vibration & Acoustics Division](#)
- [ISO Vibration Standards](#), [National Instruments](#), [SKF Condition Monitoring](#)
- [Brüel & Kjær](#)

Suggested Learning Activities

- Single DOF Vibration Simulation
- Modal Analysis of Structures
- FFT-Based Signal Analysis Experiment
- Vibration Measurement Using Sensors
- Condition Monitoring Case Study
- Vibration Control Using Dampers
- Predictive Maintenance Mini Project

Suggested Text Books

1. S. S. Rao, *Mechanical Vibrations*, 6th Edition, Pearson, 2017.
2. V. P. Singh, *Mechanical Vibrations*, 4th Edition, Dhanpat Rai Publications, 2019.
3. J. S. Rao, *Vibration Condition Monitoring of Machines*, CRC Press, 2000.
4. John S. Mitchell, *Introduction to Machinery Analysis and Monitoring*, 2nd Edition, PennWell Books, 1993.
5. R. A. Collacott, *Mechanical Fault Diagnosis and Condition Monitoring*, Chapman & Hall, 1977.
6. B. C. Nakra, G. S. Yadava, and L. Thuested, *Vibration Measurement and Analysis*, National Productivity Council, 1985.
7. Ahmed A. Shabana, *Computational Dynamics*, 3rd Edition, Wiley, 2010.
8. R. B. Randall, *Vibration-Based Condition Monitoring: Industrial, Aerospace and Automotive Applications*, Wiley, 2011.
9. Andrew K. S. Jardine, Lin Ma, and Dragan Banjevic, *Maintenance, Replacement, and Reliability: Theory and Applications*, 2nd Edition, CRC Press, 2022

Course Code ME 351	ROS2 and Intelligent Robotics Laboratory						
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	-	-	2		50		
				2			1

Course Objectives The student will be able to:

1. Develop practical skills in robot programming, simulation, and analysis using RobotDK, MSC Adams, and ROS2.
2. Perform kinematic, dynamic, localization, navigation, and manipulation analyses of robotic systems using modern software tools.
3. Design, simulate, and validate robotic applications through integrated software platforms for industrial and autonomous robotic systems.

Course Outcomes Upon successful completion of the laboratory, the student will be able to:

1. Develop and simulate robotic applications using RobotDK, MSC Adams, and ROS2.
2. Analyze the kinematic, dynamic, localization, navigation, and manipulation performance of robotic systems using simulation tools.
3. Design, validate, and document robotic solutions for industrial and autonomous robotic applications using modern software platforms.

List of Experiments

Module-II: RobotDK (6 Experiments)

1. Introduction to RobotDK and industrial robot programming.
2. Robot coordinate systems, tool frame, and work object calibration.
3. Pick-and-place operation using a 6-axis articulated robot.
4. Robot path planning and trajectory generation.
5. Robot welding and machining simulation.
6. Robot painting/cutting operation and offline program generation.

Module-III: MSC Adams (5 Experiments)

7. Kinematic analysis of a single-link pendulum.
8. Kinematic and dynamic analysis of a four-bar mechanism.
9. Kinematic and dynamic analysis of a slider-crank mechanism.
10. Kinematic and dynamic analysis of a two-link (RR) robotic manipulator.
11. Trajectory and workspace analysis of a robotic manipulator.

Module-IV: ROS2 (9 Experiments)

12. Installation and configuration of the ROS2 environment.
13. Creating and building a ROS2 package.
14. Publisher–Subscriber communication using ROS2.
15. Service–Client communication and Action interfaces.
16. Robot modeling using URDF and visualization in RViz2.

17. Robot simulation using Gazebo.
18. Mobile robot localization using AMCL.
19. Autonomous navigation and path planning using Navigation2.
20. Pick-and-place simulation using MoveIt2

Module-IV: 6 axis articulated robot (2 Experiments)

21. To perform a pick and place operation
22. To perform a path planning operation

Optional Experiments

23. Digital twin of a robotic manipulator
24. Vision-guided robotic sorting
25. Collaborative robot simulation

Note; At least 12 experiments are to be completed by the student in a single semester.

Course Code ME 361	SEMINAR						
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	-	-	2	2	50		1

Course Objectives:

- Understand the purpose of seminar and Importance of literature review
- Learn the resources available at the college and outside for pursuing project
- Learn to document results and arrive at required conclusions

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

1. Identify engineering problems reviewing available literature.
2. Study the different techniques adopted to solve the problem.
3. Understand the usage of related techniques and software's
4. Investigate the procedure adopted and Interpret the results and conclusions obtained
5. Document the findings as a technical report with proper references.

The seminar must be clearly structured and Power point presentation should include the following:

1. Introduction
2. Literature survey
3. Consolidation of available information
4. Objectives and Methodology
5. Results and Discussions
6. Conclusions
7. References

Seminar topics may be chosen by the students with advice from the faculty members and the student shall read further relevant articles in the domain.

The seminar must be clearly structured and the power point presentation shall include following aspects:

1. Introduction to the field
2. Literature survey
3. Consolidation of available information
4. Objectives and Methodology
5. Results and Discussions & Summary
6. Conclusions
7. References

Each student is required to:

1. Deliver the seminar for a maximum duration of 30 minutes, where the presentation

should be for 20 minutes in PowerPoint, followed by Question and Answers session for 10 minutes.

2. Submit the detailed report of the seminar in spiral bound in a précised format as suggested by the Department.

Guidelines for awarding marks		
S. No.	Description	Max. Marks
1	Contents and relevance	10
2	Presentation skills	10
3	Preparation of PPT slides	05
4	Questions and answers	05
5	Report in a prescribed format	20

Note:

1. The seminar presentation should be a gist of few research papers from Peer-reviewed or UGC recognized journals.
2. The seminar report should be in the following order: Background of work, literature review, techniques used, prospective deliverables, discussion on results, conclusions, critical appraisal and references
3. At least two faculty members will be associated with the seminar presentation to evaluate and award marks.
4. Attendance of all the students for weekly seminar presentations is compulsory.

SEMESTER - II

Course Code ME 304	DYNAMIC LOCOMOTION AND LEGGED ROBOTICS (Programme Core)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the principles of legged locomotion and biological inspiration.
 - Develop mathematical models of legged robots using kinematics and multibody dynamics.
 - Analyze gait generation, stability, and balance control for biped and quadruped robots.
 - Apply advanced control strategies for dynamic locomotion.
- Explore autonomous locomotion and emerging trends in intelligent legged robotic systems.

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

1. Analyze the kinematic and dynamic behavior of legged robotic systems.
2. Develop gait generation and balance control strategies for walking and running robots.
3. Apply dynamic models to study stability and locomotion performance.
4. Design motion planning and control algorithms for legged robots.
5. Evaluate modern approaches including reinforcement learning for dynamic locomotion.

UNIT – I Introduction to Legged Robotics and Locomotion

Biological inspiration for locomotion, classification of legged robots, biped, quadruped, hexapod and humanoid robots, locomotion fundamentals, degrees of freedom, kinematic modeling of legged robots, gait terminology, support polygons, static and dynamic stability, applications of legged robots in industry, defense, healthcare and exploration.

UNIT – II Dynamics of Walking and Running

Dynamic modeling of legged systems, inverted pendulum model, Linear Inverted Pendulum Model (LIPM), Spring Loaded Inverted Pendulum (SLIP) model, passive dynamic walking, rimless wheel and compass gait walker as illustrative models, running and hopping dynamics, energy efficiency in locomotion, transition between walking and running.

UNIT – III Gait Generation and Stability Control

Gait planning for bipeds and quadrupeds, walking pattern generation, center of mass motion, Zero Moment Point (ZMP), Capture Point concept, balance control, trajectory generation, footstep planning, Central Pattern Generators (CPG), disturbance rejection, push recovery strategies, stability analysis of walking robots.

UNIT – IV Control of Legged Robots

Joint-space and task-space control, inverse dynamics control, impedance and admittance control, Model Predictive Control (MPC), whole-body control, state estimation using IMU and force sensors, locomotion control architectures, control of quadruped and humanoid robots.

UNIT – V Autonomous Locomotion and Emerging Trends

Terrain perception and adaptation, locomotion on uneven terrain, stair climbing, obstacle negotiation, motion planning for legged robots, reinforcement learning for locomotion, bio-inspired locomotion, soft legged robots, exoskeletons and wearable robots, humanoid robotics, recent advances in dynamic locomotion and future trends systems.

Software / Tools Required

ROS2 (Robot Operating System), Gazebo / Ignition Gazebo Simulator, MATLAB & Simulink, Python (NumPy, SciPy, Matplotlib), MuJoCo Physics Simulator, PyBullet Physics Engine, NVIDIA Isaac Sim, OpenAI Gym / Gymnasium, Stable-Baselines3 (Reinforcement Learning), Pinocchio / RBDL (Robot Dynamics Libraries), CoppeliaSim (V-REP), Ubuntu Linux Environment, Git & GitHub

Illustrative Case Studies

- Dynamic walking of humanoid robots using Zero Moment Point (ZMP) ,Quadruped locomotion of Boston Dynamics Spot , Reinforcement Learning for quadruped robot locomotion, Stair climbing by legged robots , Uneven terrain navigation using adaptive gait planning, Push recovery in humanoid robots, Exoskeleton-assisted human walking, Disaster response using legged robots

NPTEL / SWAYAM Online Resources

- nptel.ac.in/courses/112105249(Robotics by IIT Kanpur)
- <https://nptel.ac.in/courses/112104316>(Advanced Robotics, IIT Kanpur)
- <https://nptel.ac.in/courses/112104620>(Advanced Robotics Applications, IIT Kanpur)

Professional Resources

- MIT OpenCourseWare – Underactuated Robotics
- Boston Dynamics Learning Resources
- ROS2 Official Documentation
- Open Robotics Documentation
- NVIDIA Isaac Sim Documentation
- MuJoCo Documentation
- PyBullet Documentation
- Springer Handbook of Robotics
- IEEE Robotics and Automation Society
- GitHub Robotics Projects

Suggested Learning Activities

- Install and configure ROS2 and Gazebo.
- Simulate a quadruped robot in Gazebo.
- Model an inverted pendulum using MATLAB/Simulink.
- Implement gait generation for a biped robot.
- Develop a ZMP-based balance controller.
- Implement reinforcement learning (DDPG/SAC/PPO) for robot locomotion.
- Simulate locomotion on uneven terrain.
- Study the locomotion of Boston Dynamics Spot and Unitree robots.
- Review recent IEEE research papers on dynamic locomotion.
- Complete a mini-project on autonomous legged robot navigation and obstacle avoidance.

Suggested Text Books

1. Marc H. Raibert, *Legged Robots That Balance*, MIT Press, 1986.
2. Miomir Vukobratović and Borislav Borovac, *Zero-Moment Point – Thirty-Five Years of Its Life*, Springer, 2004.
3. Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017.
4. Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, 2nd Edition, Wiley, 2020.
5. S. K. Saha, *Introduction to Robotics*, McGraw Hill Education (India), 2014.
6. Russ Tedrake, *Underactuated Robotics: Algorithms for Walking, Running, Swimming, Flying, and Manipulation*, MIT Press, 2024.
7. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
8. Steven H. Strogatz, *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*, 2nd Edition, CRC Press, 2024.
9. Jean-Jacques E. Slotine and Weiping Li, *Applied Nonlinear Control*, Prentice Hall, 1991.
10. Gordon Cheng, *Humanoid Robotics and Neuroscience: Science, Engineering and Society*, CRC Press, 2018.
11. Shuuji Kajita, Hirohisa Hirukawa, Kensuke Harada, and Kazuhito Yokoi, *Introduction to Humanoid Robotics*, Springer, 2014.
12. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, 2018.

Course Code ME 305	MOTION PLANNING AND AUTONOMOUS NAVIGATION (Program Core)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the mathematical foundations of robot motion planning and autonomous navigation.
- Develop configuration space representations for mobile robots and manipulators.
- Learn classical and modern path planning algorithms for robotic systems.
- Understand localization, mapping and obstacle avoidance techniques.
- Apply intelligent motion planning methods for autonomous robots operating in dynamic environments.

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

1. Model robotic systems using configuration space representations and environmental maps.
2. Develop localization and mapping techniques for autonomous robotic systems.
3. Apply graph-based, sampling-based and optimization-based path planning algorithms.
4. Design obstacle avoidance and navigation strategies for mobile robots and manipulators.
5. Analyze intelligent motion planning techniques for autonomous robots operating in complex environments.

UNIT – I Configuration Space and Robot Modeling

Review of robot kinematics and transformations, configuration space representation, degrees of freedom, workspace and configuration space obstacles, holonomic and non-holonomic constraints, mobile robot models, manipulator configuration spaces, environment representation, occupancy grid maps, topological maps and roadmap representations.

UNIT – II Localization and Mapping

Sensors used in autonomous navigation, wheel encoders, IMU, LiDAR, cameras and GPS, dead reckoning and odometry, Bayesian localization, Kalman Filter, Extended Kalman Filter (EKF), Particle Filter, occupancy grid mapping, topological mapping, introduction to Simultaneous Localization and Mapping (SLAM), visual SLAM and LiDAR SLAM.

UNIT – III Path Planning Algorithms

Graph-based search methods including Dijkstra's Algorithm and A* Algorithm, visibility graphs, Voronoi diagrams, potential field methods, sampling-based planners including Probabilistic Road Maps (PRM), Rapidly Exploring Random Trees (RRT), trajectory generation and path smoothing techniques.

UNIT – IV Autonomous Navigation and Manipulation Planning

Global and local navigation, obstacle avoidance techniques, Dynamic Window Approach (DWA), velocity obstacle methods, navigation in dynamic environments, motion planning for

robotic manipulators, trajectory tracking, multi-robot navigation and cooperative motion planning.

UNIT – V Intelligent Motion Planning and Emerging Applications

Optimization-based planning, Model Predictive Control (MPC) for navigation, reinforcement learning for motion planning, behavior-based navigation, human-aware navigation, autonomous vehicle path planning, UAV motion planning, swarm robotics, digital twin-based navigation, autonomous warehouse robots and future trends in intelligent robotic navigation.

Software / Tools Required

ROS2 (Robot Operating System), Gazebo / Ignition Gazebo Simulator, MATLAB & Simulink, Python (NumPy, SciPy, Matplotlib), OpenCV, CoppeliaSim (V-REP), RViz (ROS Visualization Tool), Navigation2 (Nav2), SLAM Toolbox, MoveIt2, OMPL (Open Motion Planning Library), PyBullet / MuJoCo, Ubuntu Linux Environment, Git & GitHub

Illustrative Case Studies

- Autonomous warehouse robot navigation using ROS2
- Mobile robot localization using LiDAR-based SLAM
- Path planning using A* and Dijkstra algorithms
- Obstacle avoidance using Dynamic Window Approach (DWA)
- Autonomous vehicle navigation in urban environments
- UAV path planning for surveillance missions
- Robot navigation in dynamic environments using reinforcement learning
- Multi-robot cooperative navigation in warehouses

NPTEL / SWAYAM Online Resources

- nptel.ac.in/courses/112106298(Wheeled Mobile Robots, IITM IIT Palakkad)
- nptel.ac.in/courses/112104308(Robot Motion Planning, IIT Kanpur)
- [Wheeled Mobile Robots \(Mechanical Engineering\)](#)(wheeled mobile robots mechanical engineering)

Professional Resources

- ROS2 Official Documentation
- Open Robotics Documentation
- Navigation2 (Nav2) Documentation
- SLAM Toolbox Documentation
- Open Motion Planning Library (OMPL) Documentation
- OpenCV Documentation
- GitHub Robotics Projects
- MIT OpenCourseWare – Underactuated Robotics
- IEEE Robotics and Automation Society
- NVIDIA Isaac Sim Documentation

Suggested Learning Activities

- Install ROS2 and Navigation2 (Nav2).
- Create occupancy grid maps using SLAM Toolbox.
- Implement A* and Dijkstra path planning algorithms.

- Simulate mobile robot navigation in Gazebo.
- Develop obstacle avoidance using Dynamic Window Approach (DWA).
- Implement localization using EKF and Particle Filter.
- Perform trajectory planning using RRT and PRM algorithms.
- Study autonomous navigation of warehouse robots and self-driving vehicles.
- Review IEEE research papers on motion planning and autonomous navigation.
- Complete a mini-project on autonomous robot navigation with obstacle avoidance using ROS2 and Gazebo.

Suggested Text Books

1. **Steven M. LaValle**, *Planning Algorithms*, Cambridge University Press, **2006**.
2. **Sebastian Thrun, Wolfram Burgard, and Dieter Fox**, *Probabilistic Robotics*, MIT Press, **2005**.
3. **Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza**, *Introduction to Autonomous Mobile Robots*, **2nd Edition**, MIT Press, **2011**.
4. **Bruno Siciliano and Oussama Khatib (Eds.)**, *Springer Handbook of Robotics*, **2nd Edition**, Springer, **2016**.
5. **Howie Choset, Kevin M. Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia E. Kavraki, and Sebastian Thrun**, *Principles of Robot Motion: Theory, Algorithms, and Implementations*, MIT Press, **2005**.
6. **Jean-Claude Latombe**, *Robot Motion Planning*, Springer, **1991**.
7. **Maxim Lapan**, *Deep Reinforcement Learning Hands-On*, **3rd Edition**, Packt Publishing, **2024**.
8. **Richard S. Sutton and Andrew G. Barto**, *Reinforcement Learning: An Introduction*, **2nd Edition**, MIT Press, **2018**.

Course Code ME 306	MODERN CONTROL SYSTEMS (Program Core)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Develop mathematical models of dynamic systems and analyze their behavior.
- Understand classical and modern control system design techniques.
- Analyze controllability, observability, and state-space representations of dynamic systems.
- Design state feedback and optimal controllers for engineering systems.
- Apply modern control concepts to robotics and autonomous systems.

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

1. Develop mathematical models and analyze dynamic behavior of engineering systems.
2. Apply classical control techniques for stability and performance analysis.
3. Analyze controllability, observability and state-space representations of dynamic systems.
4. Design modern control systems using state feedback, observer design and optimal control techniques.
5. Apply modern control concepts to robotic and autonomous systems.

UNIT – I Mathematical Modeling and System Analysis

Mathematical modeling of mechanical, electrical and electromechanical systems, transfer functions, block diagram representation, signal flow graphs, first-order and second-order system responses, transient and steady-state analysis, steady-state error analysis, performance specifications, sensitivity analysis.

UNIT – II Classical Control System Design

Concepts of stability, poles and zeros, Routh-Hurwitz criterion, Root Locus technique, frequency response analysis, Bode plots, Nyquist stability criterion, gain margin and phase margin, lead compensator, lag compensator, lead-lag compensator design, control system performance improvement techniques.

UNIT – III State Space Analysis

State variable concepts, state-space representation of dynamic systems, state transition matrix, canonical forms, controllability and observability, controllability and observability tests, state-space modeling of robotic and electromechanical systems.

UNIT – IV Modern Control Design

State feedback control, pole placement techniques, observer design, reduced-order observers, Linear Quadratic Regulator (LQR), introduction to optimal control, introduction to Kalman filtering, applications in servo systems and robotic control.

UNIT – V Advanced Control Applications

Lyapunov stability analysis, introduction to Sliding Mode Control, fundamentals of Model Predictive Control (MPC), control of robotic manipulators, mobile robot control, trajectory tracking, autonomous navigation control concepts, UAV control systems, emerging trends in intelligent and autonomous control systems.

Software / Tools Required

MATLAB & Simulink, Python (NumPy, SciPy, Matplotlib, Control Systems Library), GNU Octave, Scilab&Xcos, LabVIEW, ROS2 (for robotic control applications), Simscape Multibody, Arduino IDE, STM32CubeIDE / Keil μ Vision, Proteus Simulation Software, Git & GitHub

Illustrative Case Studies

- PID control of DC motor speed
- Inverted pendulum stabilization
- Cruise control system for autonomous vehicles
- Quadcopter attitude and altitude control
- State-space control of robotic manipulators
- Line-following mobile robot using PID control
- Model Predictive Control (MPC) for autonomous navigation
- LQR-based control of balancing robots

NPTEL / SWAYAM Online Resources

- nptel.ac.in/courses/107106081 (Control systems IIT Madras)
- <http://elearn.psgcas.ac.in/nptel/courses/video/108101037/108101037.html> (Control engineering C-DEEPIIT Bombay)
- <http://elearn.psgcas.ac.in/nptel/courses/video/107106081/107106081.html> (Control systems Engineering design)

Professional Resources

- MATLAB & Simulink Documentation
- MathWorks Control System Toolbox Documentation
- Python Control Systems Library Documentation
- ROS2 Control Documentation
- IEEE Control Systems Society
- MIT OpenCourseWare – Feedback Control Systems
- GitHub Control Systems Projects
- Control Tutorials for MATLAB and Simulink (CTMS)
- Springer Handbook of Robotics

Suggested Learning Activities

- Model first-order and second-order systems using MATLAB/Simulink.
- Analyze system stability using Root Locus, Bode Plot, and Nyquist Plot.
- Design PID, Lead, Lag, and Lead-Lag compensators.
- Develop state-space models for dynamic systems.
- Implement LQR and observer-based control techniques.
- Simulate Model Predictive Control (MPC) for mobile robot navigation.

- Control the speed and position of a DC motor using Arduino or STM32.
- Perform laboratory experiments on inverted pendulum and servo control systems.
- Review IEEE research papers on modern control applications in robotics.
- Complete a mini-project on autonomous robot control using state-space and optimal control techniques.

Suggested Text Books

1. Katsuhiko Ogata, *Modern Control Engineering*, 5th Edition, Pearson Education, 2010.
2. I. J. Nagrath and M. Gopal, *Control Systems Engineering*, 7th Edition, New Age International Publishers, 2023.
3. Gene F. Franklin, J. David Powell, and Abbas Emami-Naeini, *Feedback Control of Dynamic Systems*, 8th Edition, Pearson, 2019.
4. Richard C. Dorf and Robert H. Bishop, *Modern Control Systems*, 14th Edition, Pearson, 2021.
5. Hassan K. Khalil, *Nonlinear Systems*, 3rd Edition, Pearson, 2002.
6. Karl J. Åström and Richard M. Murray, *Feedback Systems: An Introduction for Scientists and Engineers*, Princeton University Press, 2008.
7. Dan Simon, *Optimal State Estimation: Kalman, H_∞ , and Nonlinear Approaches*, Wiley-Interscience, 2006.
8. Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, 2nd Edition, Wiley, 2020.
9. Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017.

Course Code ME 327	SIGNAL PROCESSING FOR ROBOTICS AND AUTONOMOUS SYSTEMS (Programme Elective - IV)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-		40	60	

Course Objectives

- Understand the fundamentals of digital signal processing for robotic and autonomous systems.
- Analyze sensor signals in time and frequency domains using modern signal processing techniques.
- Design digital filters for signal conditioning, noise reduction and sensor data processing.
- Develop estimation and sensor fusion techniques for robotic perception and navigation.
- Apply signal processing methods to intelligent sensing, autonomous systems and embedded robotic platforms.

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

1. Analyze engineering signals in time and frequency domains using digital signal processing techniques.
2. Design and implement digital filters for robotic sensing and measurement applications.
3. Process and analyze signals from robotic sensors and embedded sensing systems.
4. Develop state estimation and sensor fusion algorithms for autonomous robotic systems.
5. Apply advanced signal processing techniques to robotics, autonomous systems and intelligent sensing applications.

UNIT – I Fundamentals of Digital Signal Processing

Continuous and discrete-time signals, sampling theorem, aliasing, signal reconstruction, discrete-time Fourier transform (DTFT), discrete Fourier transform (DFT), Fast Fourier Transform (FFT), spectral analysis, power spectral density estimation, signal representation in time and frequency domains, applications of DSP in robotics and autonomous systems.

UNIT – II Digital Filters and Signal Conditioning

FIR and IIR filters, filter design techniques, Butterworth and Chebyshev filters, frequency response analysis, adaptive filtering concepts, signal conditioning, noise reduction methods, sensor signal filtering, implementation of digital filters for robotic sensing systems, embedded signal processing considerations.

UNIT – III Signal Processing for Robotic Sensors and State Estimation

Noise characterization and stochastic signals, encoder signal processing, IMU signal processing, force and torque sensor signal processing, tactile sensing systems, range sensor signal processing, complementary filters, sensor calibration techniques, state estimation fundamentals, attitude estimation, orientation estimation using Euler angles and quaternions, real-time signal processing in robotic systems.

UNIT – IV Sensor Fusion and Localization

Multi-sensor systems, sensor fusion fundamentals, Kalman Filter, Extended Kalman Filter (EKF), Unscented Kalman Filter (UKF), data fusion architectures, inertial navigation concepts, IMU-GPS fusion, localization applications in mobile robots, drones and autonomous systems, practical considerations in robotic state estimation.

UNIT – V Advanced Applications in Robotics and Intelligent Systems

LiDAR signal processing, point cloud preprocessing and filtering, perception signal processing for autonomous robots, biomedical signal processing for wearable robotics, anomaly detection, intelligent sensing systems, embedded DSP platforms, edge AI concepts, signal processing in autonomous vehicles, Industry 4.0 applications and emerging trends in intelligent robotic systems.

Software / Tools Required

MATLAB & Simulink (Signal Processing Toolbox), Python (NumPy, SciPy, Pandas, Matplotlib), Jupyter Notebook / Google Colab, GNU Octave, LabVIEW, OpenCV, PCL (Point Cloud Library), Arduino IDE, STM32CubeIDE, TensorFlow / PyTorch (for AI-based signal processing), Git & GitHub

Illustrative Case Studies

- IMU signal processing for mobile robot localization
- LiDAR point cloud filtering for autonomous navigation
- GPS-IMU sensor fusion using Kalman Filter
- Noise reduction in robotic sensor signals using digital filters
- FFT-based vibration analysis for predictive maintenance
- Image and vision signal processing for autonomous robots
- Real-time obstacle detection using camera and LiDAR data
- Sensor fusion for autonomous drones and self-driving vehicles

NPTEL / SWAYAM Online Resources

- nptel.ac.in/domains/discipline/112?course=112_1 (Communication and Signal Processing)
- nptel.ac.in/courses/117103725 (Signal Processing Algorithms and Architectures, IIT Guwahati)
- [http://elearn.psgcas.ac.in/nptel/courses/video/108105055/L01.html\(digital](http://elearn.psgcas.ac.in/nptel/courses/video/108105055/L01.html(digital) signal processing – IIT Kharagpur)

Professional Resources

- MATLAB Signal Processing Toolbox Documentation
- SciPy Signal Processing Documentation
- OpenCV Documentation
- ROS2 Documentation
- Point Cloud Library (PCL) Documentation
- MathWorks DSP Tutorials
- IEEE Signal Processing Society
- IEEE Robotics and Automation Society
- GitHub Signal Processing Projects
- NVIDIA Isaac Sim Documentation

Suggested Learning Activities

- Design FIR and IIR digital filters using MATLAB and Python.
- Perform FFT and spectral analysis of robotic sensor signals.
- Process IMU, encoder, and force sensor data for state estimation.
- Implement Kalman Filter and Extended Kalman Filter (EKF) for sensor fusion.
- Process LiDAR point clouds for obstacle detection and mapping.
- Develop image processing applications using OpenCV for robot perception.
- Analyze real-time robotic sensor data using ROS2.
- Simulate sensor fusion for autonomous mobile robots and drones.
- Review IEEE research papers on signal processing for robotics and autonomous systems.
- Complete a mini-project on sensor fusion and localization for an autonomous robot using IMU, GPS, and LiDAR data.

Suggested Text Books

1. John G. Proakis and Dimitris G. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications*, 4th Edition, Pearson Education, 2007.
2. Alan V. Oppenheim and Ronald W. Schaffer, *Discrete-Time Signal Processing*, 3rd Edition, Pearson Education, 2010.
3. Sanjit K. Mitra, *Digital Signal Processing: A Computer-Based Approach*, 5th Edition, McGraw-Hill Education, 2020.
4. Steven W. Smith, *The Scientist and Engineer's Guide to Digital Signal Processing*, California Technical Publishing, 1997.
5. Dan Simon, *Optimal State Estimation: Kalman, H_∞ , and Nonlinear Approaches*, Wiley, 2006.
6. Richard G. Lyons, *Understanding Digital Signal Processing*, 3rd Edition, Pearson Education, 2011.
7. Sebastian Thrun, Wolfram Burgard, and Dieter Fox, *Probabilistic Robotics*, MIT Press, 2005.
8. Peter Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB®*, 2nd Edition, Springer, 2017.
9. Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017.

Course Code ME 328	ROBOTIC MANIPULATION, GRASPING AND FORCE CONTROL (Programme Elective - IV)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the fundamentals of robotic manipulation and object interaction.
- Analyze grasping mechanics, contact models and grasp stability in robotic systems.
- Develop grasp planning and manipulation strategies for autonomous robots.
- Study force control, tactile sensing and dexterous manipulation techniques.
- Apply perception, planning and intelligent control methods to robotic manipulation tasks.

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

1. Analyze manipulation tasks and robotic end-effector systems for object handling applications.
2. Evaluate grasp stability and grasp quality using geometric and force-based approaches.
3. Design grasp planning and manipulation strategies for robotic systems.
4. Apply force control and tactile sensing techniques for dexterous robotic manipulation.
5. Develop intelligent robotic manipulation systems integrating perception, planning and control.

UNIT – I Fundamentals of Robotic Manipulation

Introduction to robotic manipulation, manipulation taxonomy, industrial and service robot applications, manipulation tasks and challenges, robot manipulators and end-effectors, grippers and robotic hands, workspace analysis, redundancy in manipulators, object representation and coordinate frames, manipulation requirements in industrial automation, warehouse robotics and service robotics.

UNIT – II Grasping Mechanics and Contact Modeling

Robotic hands and grippers, parallel jaw grippers, vacuum grippers, adaptive grippers and multifingered robotic hands, contact models, friction cones, contact forces, grasp matrix, force closure and form closure concepts, grasp quality measures, grasp wrench space, grasp stability analysis, design considerations for robotic end-effectors and grasping devices.

UNIT – III Grasp Planning and Manipulation Strategies

Object pose estimation concepts, grasp planning methods, grasp candidate generation and evaluation, pick-and-place operations, task-space and object-space manipulation, manipulation planning frameworks, manipulation under uncertainty, grasping in cluttered environments, object regrasping strategies, manipulation sequence planning and industrial manipulation applications.

UNIT – IV Force Control and Dexterous Manipulation

Force and torque sensing, tactile sensors and tactile perception, force control strategies, impedance control, admittance control, hybrid position-force control, compliant manipulation, contact-rich manipulation, in-hand manipulation, object reorientation, dexterous manipulation with multifingered robotic hands, human-inspired manipulation techniques and manipulation safety.

UNIT – V Intelligent Robotic Manipulation Systems

Visual servoing, perception-guided manipulation, deep learning for grasp detection, grasp pose estimation, robot manipulation using ROS2 and MoveIt2, collaborative robot manipulation, warehouse automation, robotic bin picking, robotic assembly operations, mobile manipulation systems, humanoid robot manipulation, autonomous manipulation in dynamic environments and future trends in robotic manipulation.

Software / Tools Required

ROS2 (Robot Operating System), MoveIt2 Motion Planning Framework, Gazebo / Ignition Gazebo Simulator, MATLAB & Simulink (Robotics System Toolbox), Python (NumPy, SciPy, Matplotlib), CoppeliaSim (V-REP), OpenCV, NVIDIA Isaac Sim, MuJoCo Physics Simulator, PyBullet Physics Engine, RViz Visualization Tool, Ubuntu Linux Environment, Git & GitHub

Illustrative Case Studies

- Pick-and-place operation using a robotic manipulator
- Force-controlled robotic assembly of mechanical components
- Adaptive grasping of fragile objects using force sensors
- Vision-based robotic object picking in warehouses
- Peg-in-hole assembly using force and torque feedback
- Bin-picking using 3D vision and robotic manipulators
- Robotic grasp planning for irregular-shaped objects
- Collaborative robot (Cobot) manipulation in smart manufacturing

NPTEL / SWAYAM Online Resources

1. nptel.ac.in/courses/112101098(Robotics- IIT Bombay)
2. <http://elearn.psgcas.ac.in/nptel/courses/video/112107289/112107289.html>
(Robotics and control- IIT Roorkee)
3. https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_me116(Foundation of cognitive robots IIT Kanpur)

Professional Resources

- ROS2 Official Documentation
- MoveIt2 Documentation
- Open Robotics Documentation
- MATLAB Robotics System Toolbox Documentation
- OpenCV Documentation
- MuJoCo Documentation
- NVIDIA Isaac Sim Documentation
- IEEE Robotics and Automation Society
- Springer Handbook of Robotics
- GitHub Robotics Manipulation Projects

Suggested Learning Activities

- Model and simulate a robotic manipulator using ROS2 and Gazebo.
- Implement forward and inverse kinematics for a robotic arm.
- Develop motion planning for pick-and-place operations using MoveIt2.
- Simulate grasp planning for objects of different shapes and sizes.
- Implement force and torque control using virtual force sensors.
- Perform vision-based object detection and robotic grasping using OpenCV.
- Analyze manipulator workspace and singularity conditions.
- Simulate peg-in-hole assembly using force feedback control.
- Review IEEE research papers on robotic manipulation, grasping, and force control.
- Complete a mini-project on autonomous robotic pick-and-place with vision-guided grasping and force-controlled manipulation.

Suggested Text Books

1. Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017.
2. Matthew T. Mason, *Mechanics of Robotic Manipulation*, MIT Press, 2001.
3. Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo, *Robotics: Modelling, Planning and Control*, Springer, 2009.
4. Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, 2nd Edition, Wiley, 2020.
5. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
6. Peter Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB®*, 2nd Edition, Springer, 2017.
7. Richard M. Murray, Zexiang Li, and S. Shankar Sastry, *A Mathematical Introduction to Robotic Manipulation*, CRC Press, 2017 (Reprint Edition).
8. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, 2018.
9. Aaron Martinez and Enrique Fernández, *Learning ROS for Robotics Programming*, 2nd Edition, Packt Publishing, 2018.

Course Code ME 329	INTELLIGENT FLUID POWER SYSTEMS (Programme Elective - IV)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the principles of hydraulic and pneumatic actuation systems used in Mechanical Engineering
- Analyze the performance of hydraulic and pneumatic components and servo systems.
- Develop mathematical models of fluid power actuators and control systems.
- Design electro-hydraulic and electro-pneumatic systems for industrial applications.
- Apply intelligent fluid power technologies in robotics, mobile machinery and smart automation systems.

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

1. Analyze hydraulic and pneumatic actuation systems used in industrial applications.
2. Evaluate the performance of fluid power components and servo control systems.
3. Develop mathematical models of hydraulic and pneumatic actuation systems.
4. Design electro-hydraulic and electro-pneumatic systems for industrial applications.
5. Apply intelligent fluid power technologies in robotic, industrial and autonomous systems.

UNIT – I Fundamentals of Fluid Power

Advantages and limitations of fluid power systems, hydraulic fluids, physical, chemical and thermal properties of hydraulic fluids, selection of hydraulic fluids, fluid flow fundamentals. Hydraulic pumps and motors: basic types and construction, ideal pump and motor analysis, performance characteristics and parameters, introduction to intelligent fluid power systems and industrial applications.

UNIT – II Hydraulic Components and Electro-Hydraulic Control Systems

Hydraulic control valves: valve configurations, general valve analysis, critical centre, open centre, three-way spool valve analysis and flapper valve analysis, pressure control valves, single-stage and two-stage pressure control valves, flow control valves, proportional and servo valves, introduction to electro-hydraulic control systems, sensors and transducers used in hydraulic systems.

UNIT – III Hydraulic Servo Systems

Hydraulic power elements: valve-controlled motor, valve-controlled piston, three-way valve-controlled piston, pump-controlled motor, pressure transients in hydraulic power elements. Hydraulic servo systems, electro-hydraulic positioning systems, pressure and load dynamics, applications in machine tools, industrial automation and heavy-duty equipment.

UNIT – IV Pneumatic Automation

Characteristics and applications of pneumatics, basic pneumatic elements, pneumatic servomechanisms, pneumatic servo systems, ram equations, load sensitivity, methods of stabilization, stabilization using auxiliary tanks, electro-pneumatic control systems, PLC-based pneumatic automation, practical aspects of pneumatic servo testing and design.

UNIT – V: Intelligent Fluid Power Systems

Control of pressure, flow and speed in hydraulic and pneumatic systems, fluidics: proportional amplifier, bistable amplifier, vortex amplifier, turbulence amplifier, impact modulator, Boolean algebra, fluid logic, manipulation of logic expressions, special and sequential circuits, condition monitoring and fault diagnosis of fluid power systems, sensor-integrated hydraulic and pneumatic systems, predictive maintenance, Industrial Internet of Things (IIoT) for fluid power systems, and emerging trends in intelligent fluid power engineering.

Software / Tools Required

MATLAB & Simulink (Simscape Fluids), Automation Studio, AMESim (Siemens Simcenter Amesim), FluidSIM (Festo), ROS2 (Robot Operating System), Python (NumPy, SciPy, Matplotlib), LabVIEW, PLC Programming Software (TIA Portal / CODESYS), Arduino IDE, SolidWorks / Autodesk Inventor, ANSYS Fluent (for fluid flow analysis), Git & GitHub

Illustrative Case Studies

- Electro-hydraulic actuator control for robotic manipulators
- Electro-pneumatic pick-and-place robotic system
- Hydraulic robotic arm for heavy material handling
- Intelligent fluid power control in excavators
- Pneumatic soft robotic gripper for fragile object handling
- Hydraulic leg actuation in quadruped robots
- Servo-hydraulic control of industrial robotic systems
- Predictive maintenance of hydraulic and pneumatic systems using IoT

NPTEL / SWAYAM Online Resources

- nptel.ac.in/courses/112106175 (Fluid Power Control, IIT Madras)
- nptel.ac.in/courses/108107589 (Intelligent Control of Robotic Systems, IIT Roorkee)

Professional Resources

- Festo Didactic Learning Portal
- Bosch Rexroth Hydraulic Training Resources
- Parker Hannifin Fluid Power Training
- Siemens Simcenter Amesim Documentation
- MATLAB Simscape Fluids Documentation
- Automation Studio Documentation
- IEEE Robotics and Automation Society
- International Fluid Power Society (IFPS)
- National Fluid Power Association (NFPA)
- GitHub Fluid Power and Robotics Projects

Suggested Learning Activities

- Design and simulate hydraulic and pneumatic circuits using Automation Studio or FluidSIM.
- Model electro-hydraulic actuators using MATLAB/Simulink (Simscape Fluids).
- Develop a PLC-based electro-pneumatic control system for industrial automation.
- Simulate a robotic arm actuated by hydraulic and pneumatic systems.
- Analyze the performance of servo valves and proportional control valves.
- Integrate pressure, flow, and position sensors with fluid power systems.
- Implement IoT-based condition monitoring and predictive maintenance for hydraulic systems.
- Study industrial applications of intelligent fluid power in construction, manufacturing, and robotics.
- Review IEEE research papers on robotic actuation and intelligent fluid power systems.
- Complete a mini-project on designing an intelligent electro-hydraulic or electro-pneumatic robotic actuator with closed-loop control.

Suggested Text Books

1. Anthony Esposito, *Fluid Power with Applications*, 9th Edition, Pearson Education, 2013.
2. Herbert E. Merritt, *Hydraulic Control Systems*, John Wiley & Sons, 1967.
3. Andrew Parr, *Hydraulics and Pneumatics: A Technician's and Engineer's Guide*, 3rd Edition, Elsevier (Butterworth-Heinemann), 2011.
4. John Watton, *Fundamentals of Fluid Power Control*, Cambridge University Press, 2009.
5. Arthur Akers, Max Gassman, and Richard Smith, *Hydraulic Power System Analysis*, CRC Press, 2006.
6. D. McCloy and H. R. Martin, *The Control of Fluid Power: Analysis and Design*, 2nd Edition, Ellis Horwood, 1980.
7. Joji P. and S. R. Majumdar, *Pneumatic Systems: Principles and Maintenance*, Tata McGraw-Hill Education, 1999.
8. Peter Rohner, *Fluid Power Logic Circuit Design*, Macmillan Press, 1979.
9. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.

Course Code ME 330	MULTI-ROBOT SYSTEMS AND SWARM ROBOTICS (Programme Elective - IV)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the fundamentals of multi-robot systems and swarm intelligence.
- Learn coordination, communication and cooperation strategies among multiple robots.
- Study distributed control, consensus algorithms and formation control techniques.
- Develop task allocation and cooperative decision-making algorithms.
- Apply swarm robotics principles to real-world robotic and autonomous systems.

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

1. Explain the principles and architectures of multi-robot systems and swarm robotics.
2. Develop communication and coordination strategies for cooperative robotic systems.
3. Apply consensus, formation control and distributed control techniques.
4. Design task allocation and cooperative planning algorithms for multi-robot systems.
5. Implement swarm intelligence methods for autonomous robotic applications.

UNIT – I Introduction to Multi-Robot Systems and Swarm Robotics

Introduction to multi-robot systems, advantages and challenges of multi-robot systems, centralized and decentralized architectures, swarm intelligence principles, biological inspirations from ants, bees, birds and fish schools, characteristics of swarm robotics, applications in logistics, agriculture, surveillance, search and rescue, warehouse automation and autonomous transportation.

UNIT – II Communication and Coordination in Multi-Robot Systems

Robot communication architectures, distributed information sharing, cooperative sensing, coordination strategies, leader-follower approaches, behavior-based coordination, synchronization, network topology, connectivity analysis, fault tolerance and robustness in multi-robot systems.

UNIT – III Consensus Algorithms and Formation Control

Graph theory fundamentals, graph representations, network connectivity, consensus problems, average consensus algorithms, distributed control methods, formation control techniques, leader-follower formations, virtual structure approaches, behavior-based formations, flocking algorithms, Vicsek model, rendezvous problems and cooperative navigation.

UNIT – IV Task Allocation and Cooperative Planning

Multi-robot task allocation problem, auction-based methods, market-based approaches, contract net protocol, cooperative path planning, conflict resolution, resource allocation, coverage planning, area exploration, cooperative localization and decision making under uncertainty.

UNIT – V Swarm Intelligence and Advanced Applications

Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Bee Colony Optimization, collective behavior models, swarm learning, reinforcement learning for swarms, collective decision making, swarm exploration, multi-UAV coordination, warehouse robot fleets, autonomous vehicle platoons, robot soccer, industrial applications, ROS2 multi-robot systems and future trends in swarm robotics.

Software / Tools Required

ROS2 (Robot Operating System 2), Gazebo / Ignition Gazebo Simulator, MATLAB & Simulink, Python (NumPy, SciPy, Matplotlib), C++, CoppeliaSim (V-REP), Webots Robot Simulator, ARGoS Multi-Robot Simulator, OpenCV, NVIDIA Isaac Sim, Docker, Git & GitHub

Illustrative Case Studies

- Multi-robot warehouse automation using Autonomous Mobile Robots (AMRs)
- Swarm-based search and rescue operations
- Formation control of mobile robot teams
- Cooperative object transportation by multiple robots
- Drone swarm for environmental monitoring and surveillance
- Swarm robotics for agricultural field monitoring
- Multi-robot exploration and mapping (Multi-Robot SLAM)
- Autonomous delivery robots in smart cities

NPTEL / SWAYAM Online Resources

- https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_me76(Robotics – IIT Kharagpur)
- https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_me139(micro-Robotics IIT Indore)

Professional Resources

- ROS2 Official Documentation
- Open Robotics Documentation
- ARGoS Multi-Robot Simulator Documentation
- Webots Documentation
- Gazebo Simulator Documentation
- OpenCV Documentation
- IEEE Robotics and Automation Society
- Swarm Intelligence Journal (Springer)
- GitHub Multi-Robot Projects
- NVIDIA Isaac Sim Documentation

Suggested Learning Activities

- Install and configure ROS2 and Gazebo for multi-robot simulation.
- Simulate multiple mobile robots performing cooperative navigation.

- Implement formation control algorithms for robot teams.
- Develop swarm behaviors such as flocking, aggregation, and dispersion.
- Implement cooperative task allocation using multi-agent systems.
- Simulate Multi-Robot SLAM for collaborative mapping.
- Develop communication between robots using ROS2 topics, services, and DDS.
- Analyze swarm optimization algorithms such as Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) for robotic applications.
- Review IEEE research papers on multi-robot systems and swarm robotics.
- Complete a mini-project on cooperative multi-robot exploration and autonomous navigation using ROS2 and Gazebo.

Suggested Text Books

1. Heiko Hamann, *Swarm Robotics: A Formal Approach*, Springer International Publishing, 2018.
2. Erol Şahin and William M. Spears (Eds.), *Swarm Robotics: SAB 2004 International Workshop, Revised Selected Papers*, Springer, 2005.
3. Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd Edition, MIT Press, 2011.
4. Sabine Hauert and James Sharpe (Eds.), *Swarm Robotics: From Biology to Robotics*, Springer, 2018.
5. Howie Choset, Kevin M. Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia E. Kavraki, and Sebastian Thrun, *Principles of Robot Motion: Theory, Algorithms, and Implementations*, MIT Press, 2005.
6. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
7. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, 2018.
8. Steven M. LaValle, *Planning Algorithms*, Cambridge University Press, 2006.
9. Marco Dorigo and Thomas Stützle, *Ant Colony Optimization*, MIT Press, 2004.

Course Code ME106	ADDITIVE MANUFACTURING TECHNOLOGIES AND APPLICATIONS (Program Elective - IV)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives:

- To know the fundamentals of Additive Manufacturing (AM)
- Compare fundamentals of Additive Manufacturing (AM) with conventional CNC technology
- To understand the working principle, advantages, limitations and applications of various AM Technologies
- To study about various types of data formats and errors.
- To know the role of AM in Topology optimization and understand the applications of AM in various fields like Biomedical, Aerospace, Automobile and other domains.

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

1. Interpret the features of Additive Manufacturing and compare it with
2. conventional CNC Technology
3. Illustrate the working principle, advantages, limitations and applications of various Additive Manufacturing Technologies and Rapid Tooling systems
4. Interpret various types data formats and STL file errors used in AM and identify the role of Topology optimization in AM
5. Analyze the features of different types of software's used in 3D Printing technology

UNIT – I

Introduction: Prototyping fundamentals: Need for time compression in product development, Need for Additive Manufacturing, Historical development, Fundamentals of Additive Manufacturing, AM Process Chain, Advantages and Limitations of AM, Commonly used Terms, Classification of AM process, Fundamental Automated Processes: Distinction between AM and CNC, other related technologies. Role of AM in Industry 4.0.

UNIT – II

Working principle, Specifications, Materials used, Process, Applications, Advantages and Disadvantages, Case studies of the following AM Technologies

VatPhotopolymerization AM Systems: Photopolymers, photo polymerization Stereo lithography Apparatus (SLA), Direct Light Processing (DLP) and Continuous Direct Light Processing (CDLP).

Material Jetting AM Systems: Material Jetting, Nano particle jetting and Drop-On-Demand (DOD) material jetting **Binder JettingAM Systems:** Three dimensional Printing (3DP).

Material ExtrusionAM Systems: Fused Deposition Modeling (FDM)

UNIT – III

Working principle, Specifications, Materials used, Process, Applications, Advantages and Disadvantages, Case studies of the following AM Technologies

Powder Bed Fusion AM Systems: Selective laser sintering (SLS), Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM).

Direct Energy Deposition (DED) AM Systems: Laser Engineered Net Shaping (LENS) and Electron Beam Additive Manufacturing (EBAM).

Sheet Lamination AM Systems: Laminated Object Manufacturing (LOM) and Ultrasonic Additive Manufacturing (UAM).

Rapid Tooling: Introduction to Rapid Tooling (RT), Conventional Tooling Vs RT, Need for RT, Classification of Rapid Tooling, Direct and Indirect Tooling Methods, Soft and Hard Tooling methods.

UNIT – IV

Reengineering in AM: Reengineering Engineering (RE) Methodologies and Techniques, Selection of RE systems, RE software, RE hardware, RE in product development

AM Data Formats: STL Format, STL File Problems, Consequence of Building Valid and Invalid Tessellated Models, STL file Repairs: Generic Solution, Slicing Algorithms: Rock Algorithm, Crawford's algorithm, Other Translators, Newly Proposed Formats. Mesh Refining by Sub division Techniques, Topology optimization and Additive Manufacturing.

AM Software's: Need for AM software, Features of various AM software's like Magics, Mimics, Solid View, View Expert, 3 D View, Velocity 2, Rhino, STL View 3 Data Expert and 3 D doctor, SurgiGuide, 3-matic, Simplant, MeshLab.

UNIT –V

AM Applications: Application – Material Relationship, Application in Design, Engineering Analysis and Planning, Aerospace, Automotive, Jewelry, Coin, GIS, Arts, Architecture. Medical and Bioengineering Applications, Forensic Science and Anthropology, Visualization of Biomolecules.**Cost Estimation in AM:** Cost Model, Build Time Model, Laser Scanning Vat Photopolymerization Example, Life-Cycle Costing.

Software / Tools Required

SolidWorks, CATIA, Autodesk Fusion 360, Siemens NX, ANSYS, Abaqus, MATLAB & Simulink, Materialise Magics, Materialise Mimics, MeshLab, Blender, Rhino 3D, Netfabb, Cura, Simplify3D

Illustrative Case Studies

- FDM-Based Prototype Development
- Metal Additive Manufacturing for Aerospace Components
- Topology Optimization for Lightweight Design
- Medical Implant Fabrication Using 3D Printing
- Rapid Tooling for Injection Mold Development

NPTEL / SWAYAM Online Resources

- Additive Manufacturing Process — <https://nptel.ac.in/courses/112104225>
- Rapid Manufacturing — <https://nptel.ac.in/courses/112104226>
- ManufacturingTechnologyAdditiveManufacturingModule<https://nptel.ac.in/courses/112105305>

Professional Resources

- [ASTM International – Additive Manufacturing](#)

- [ISO – Additive Manufacturing Standards](#)
- [Materialise](#)
- [EOS GmbH](#)
- [Stratasys](#)

Suggested Learning Activities

- 3D CAD Modeling for Additive Manufacturing
- STL File Preparation and Slicing
- 3D Printing Laboratory Experiments
- Reverse Engineering and Topology Optimization
- Rapid Tooling Case Study Analysis
- Mini Project on Additive Manufacturing Applications
- Seminar on Industry 4.0 and Additive Manufacturing

Suggested Readings:

1. **Ian Gibson, David W. Rosen, and Brent Stucker**, *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing*, **3rd Edition**, Springer, **2021**.
2. **Chee Kai Chua, Kah Fai Leong, and Chu Sing Lim**, *3D Printing and Additive Manufacturing: Principles and Applications*, **6th Edition**, World Scientific Publishing, **2023**.
3. **Frank W. Liou**, *Rapid Prototyping and Engineering Applications: A Toolbox for Prototype Development*, CRC Press, Taylor & Francis Group, **2011**.
4. **Rafiq Noorani**, *Rapid Prototyping: Principles and Applications in Manufacturing*, John Wiley & Sons, **2006**.
5. **Andreas Gebhardt and Jan-Steffen Hötter**, *Additive Manufacturing: 3D Printing for Prototyping and Manufacturing*, **2nd Edition**, Hanser Publishers, **2016**.
6. **Andreas Gebhardt and Jan-Steffen Hötter**, *Additive Manufacturing: 3D Printing for Prototyping and Manufacturing*, **3rd Edition**, Hanser Publishers, **2021**.
7. **Wohlers Associates**, *Wohlers Report 2025: Additive Manufacturing and 3D Printing State of the Industry*, Wohlers Associates, **2025**.
8. **J. Paulo Davim (Ed.)**, *Additive Manufacturing: Materials, Processes, Quantifications and Applications*, Elsevier, **2018**.
9. **Lihui Wang and Y. Wang (Eds.)**, *Cloud-Based Additive Manufacturing*, Springer, **2018**.

Course Code ME 331	MACHINE LEARNING FOR MECHANICAL SYSTEMS (Program Elective – V)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Outcomes

1. Understand the fundamentals of machine learning and data analytics.
2. Learn supervised, unsupervised, and deep learning techniques for engineering applications.
3. Understand computer vision and intelligent perception methods.
4. Apply machine learning techniques to solve engineering problems.
5. Explore applications of machine learning in Mechanical Engineering and smart manufacturing.

Course Outcomes (COs) After successful completion of the course, the student will be able to:

1. Explain the fundamentals of machine learning and data analytics.
2. Apply supervised and unsupervised learning algorithms to engineering problems.
3. Develop basic deep learning models for data analysis and prediction.
4. Apply computer vision techniques for image processing and intelligent perception.
5. Apply machine learning techniques to Mechanical Engineering applications such as predictive maintenance, manufacturing, quality control, and intelligent automation.

UNIT – I Introduction to Machine Learning and Data Analytics

Artificial Intelligence, Machine Learning and Deep Learning, data acquisition and preprocessing, data cleaning, feature engineering, data transformation, training and testing datasets, model evaluation metrics, overfitting and underfitting, bias-variance tradeoff, cross-validation, linear regression techniques, logistic regression, regularization methods and model selection techniques.

UNIT – II Supervised and Unsupervised Learning

Gradient descent method, support vector machines, kernel methods, decision trees, random forests, ensemble learning methods, clustering techniques, K-means clustering, hierarchical clustering, principal component analysis (PCA), dimensionality reduction and feature extraction.

UNIT – III Neural Networks and Deep Learning

Artificial neurons, perceptrons, multilayer neural networks, activation functions, backpropagation algorithm, optimization methods, regularization techniques, hyperparameter tuning, convolutional neural networks (CNNs), recurrent neural networks (RNNs), Long

Short-Term Memory (LSTM) networks, transfer learning, introduction to autoencoders and deep learning frameworks.

UNIT – IV Computer Vision and Intelligent Perception

Image representation, feature extraction, image classification, object detection, semantic segmentation, computer vision pipelines, robot perception, sensor data interpretation, vision-based decision making, applications in robotics and autonomous systems.

UNIT – V Applications of Machine Learning in Mechanical Engineering

Applications of machine learning in predictive maintenance, fault diagnosis, condition monitoring, remaining useful life prediction, manufacturing process optimization, machining and tool wear prediction, quality control and defect detection, additive manufacturing, production planning and scheduling, structural health monitoring, thermal and energy systems, turbomachinery performance prediction, intelligent robotics and automation, digital twins for mechanical systems, smart manufacturing, and emerging AI-enabled mechanical engineering applications.

Software / Tools Required

Python, Anaconda Distribution, Jupyter Notebook, Google Colab, Visual Studio Code (VS Code), Scikit-learn, TensorFlow, Keras, PyTorch, OpenCV, Pandas, NumPy, Matplotlib, Seaborn, Git & GitHub

Illustrative Case Studies

- Predictive maintenance of industrial machinery using machine learning
- Fault diagnosis of rotating machinery using vibration data
- Computer vision for defect detection in manufacturing
- Robot path planning using Reinforcement Learning (DDPG, PPO, SAC)
- Object detection for autonomous robots using CNNs
- Human activity recognition using wearable sensor data
- Digital Twin-based predictive analytics for smart manufacturing
- Autonomous vehicle perception and obstacle detection

NPTEL / SWAYAM Online Resources

- nptel.ac.in/courses/106106198 (Machine Learning for Engineering and science applications, – IIT Madras)
- https://onlinecourses.swayam2.ac.in/e-learning/preview/ini25_cs02 (Machine Learning Using Python Programming, Institute of science BHU)

Professional Resources

- Scikit-learn Official Documentation
- TensorFlow Official Documentation
- PyTorch Documentation
- OpenCV Documentation
- Kaggle
- Papers with Code
- GitHub Machine Learning Projects
- IEEE Computational Intelligence Society
- IEEE Robotics and Automation Society

- Google AI and TensorFlow Tutorials

Suggested Learning Activities

- Install and configure Python, Anaconda, and Jupyter Notebook.
- Implement Linear Regression and Logistic Regression using Scikit-learn.
- Develop classification models using Decision Trees, Random Forests, and Support Vector Machines.
- Perform clustering using K-Means and Hierarchical Clustering.
- Apply Principal Component Analysis (PCA) for dimensionality reduction.
- Design and train Convolutional Neural Networks (CNNs) for image classification.

Suggested Text Books

1. **Christopher M. Bishop**, *Pattern Recognition and Machine Learning*, Springer, 2006.
2. **Aurélien Géron**, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*, 3rd Edition, O'Reilly Media, 2022.
3. **Ian Goodfellow, Yoshua Bengio, and Aaron Courville**, *Deep Learning*, MIT Press, 2016.
4. **Kevin P. Murphy**, *Machine Learning: A Probabilistic Perspective*, MIT Press, 2012
5. NPTEL, *Rapid Manufacturing*, IIT Kanpur/IIT Bombay, **Latest Online Course**.

Course Code ME 332	BIO-INSPIRED ROBOTICS AND INTELLIGENT SYSTEMS (Programme Elective - V)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand biological principles that inspire robotic design and intelligent systems.
- Learn locomotion mechanisms observed in animals, insects, birds and aquatic organisms.
- Study bio-inspired sensing, control and decision-making strategies.
- Develop mathematical models of biological systems for robotic applications.
- Apply bio-inspired concepts to design autonomous and adaptive robotic systems.

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

1. Explain biological principles underlying bio-inspired robotics and intelligent systems.
2. Analyze various biological locomotion mechanisms and their robotic implementations.
3. Develop bio-inspired sensing and control systems for robotic applications.
4. Apply swarm intelligence and collective behavior principles to autonomous robotic systems.
5. Design and evaluate bio-inspired robotic solutions for engineering applications.

UNIT – I Introduction to Bio-Inspired Robotics

Introduction to bio-inspired engineering, biological systems as models for engineering design, evolution of bio-inspired robotics, biological adaptation and intelligence, Central Pattern Generators (CPG), biomimetics and bio-inspiration, morphology and function in biological organisms, applications of bio-inspired robotics in industry, healthcare, agriculture and autonomous systems.

UNIT – II Bio-Inspired Locomotion Systems

Animal locomotion principles, walking, running, hopping and climbing mechanisms, insect-inspired locomotion, quadruped and hexapod robots, snake robots and limbless locomotion, bird-inspired flight, flapping wing robots, fish-inspired underwater locomotion, swimming robots, soft locomotion systems, modeling and analysis of bio-inspired locomotion, case studies of bio-inspired robotic systems.

UNIT – III Bio-Inspired Sensing and Perception

Biological sensing systems, vision systems in insects and animals, echolocation in bats and dolphins, tactile sensing inspired by whiskers and skin receptors, proprioception and balance systems, bio-inspired sensor design, neuromorphic sensing, sensor fusion, perception in biological and robotic systems, applications in autonomous navigation and environmental interaction.

UNIT – IV Swarm Intelligence and Collective Behavior

Collective intelligence in nature, ant colonies, bee swarms, bird flocking and fish schooling, emergence and self-organization, Vicsek model, swarm robotics principles, Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), cooperative robotics, distributed decision making, multi-agent coordination, applications in autonomous robotic systems.

UNIT – V Bio-Inspired Learning, Adaptation and Applications

Neural mechanisms of learning and adaptation, artificial neural networks inspired by biological systems, reinforcement learning inspired by animal behavior, evolutionary robotics, genetic algorithms, embodied intelligence, soft robotics, bio-inspired manipulation systems, exoskeletons, medical robotics, search-and-rescue robotics and future trends in bio-inspired intelligent systems.

Software / Tools Required

ROS2 (Robot Operating System 2), MATLAB & Simulink, Python (NumPy, SciPy, Matplotlib), CoppeliaSim (V-REP), Gazebo / Ignition Gazebo Simulator, MuJoCo Physics Simulator, PyBullet Physics Engine, OpenCV, NVIDIA Isaac Sim, TensorFlow / PyTorch, OpenAI Gym / Gymnasium, Stable-Baselines3 (Reinforcement Learning), Git & GitHub

Illustrative Case Studies

- Bio-inspired locomotion of quadruped robots (Unitree Go1, Boston Dynamics Spot)
- Snake robot for pipeline inspection and search & rescue operations
- Fish-inspired underwater robot for ocean exploration
- Bird-inspired flapping-wing drone (Ornithopter)
- Gecko-inspired wall-climbing robot using adhesive mechanisms
- Swarm intelligence in ant-inspired and bee-inspired robotic systems
- Soft robotic gripper inspired by octopus tentacles
- Reinforcement learning for insect-inspired autonomous navigation

NPTEL / SWAYAM Online Resources

- nptel.ac.in/courses/108107589 (Intelligent Control of Robotic Systems, IIT Roorkee)
- (https://onlinecourses.nptel.ac.in/noc20_me92/preview) Foundations of Cognitive Robotics

Professional Resources

- ROS2 Official Documentation
- Open Robotics Documentation
- MuJoCo Documentation
- NVIDIA Isaac Sim Documentation
- OpenCV Documentation
- TensorFlow Documentation
- PyTorch Documentation
- IEEE Robotics and Automation Society
- Springer Handbook of Robotics
- GitHub Bio-inspired Robotics Projects

Suggested Learning Activities

- Simulate bio-inspired robots using ROS2 and Gazebo.
- Model quadruped, snake, or fish-inspired robots in MuJoCo or PyBullet.
- Implement reinforcement learning algorithms (PPO, DDPG, or SAC) for bio-inspired locomotion.
- Develop vision-based navigation for autonomous robots using OpenCV.
- Design and simulate a soft robotic gripper inspired by biological systems.
- Analyze swarm intelligence algorithms inspired by ants, bees, and birds.
- Study the locomotion mechanisms of insects, birds, fish, and mammals for robotic applications.
- Review IEEE research papers on bio-inspired robotics and intelligent systems.
- Explore AI-based adaptive control techniques for bio-inspired robots.
- Complete a mini-project on designing and simulating a bio-inspired robot for autonomous navigation, inspection, or search-and-rescue applications.

Suggested Textbooks

1. Yoseph Bar-Cohen (Ed.), *Biomimetics: Nature-Based Innovation*, CRC Press, 2011.
2. Peter Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB® and Python*, 3rd Edition, Springer, 2023.
3. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
4. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, 2018.
5. Dario Floreano and Claudio Mattiussi, *Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies*, MIT Press, 2008.
6. Metin Sitti, *Mobile Microrobotics*, MIT Press, 2017.
7. Rolf Pfeifer, Josh Bongard, and Colin Wilson, *How the Body Shapes the Way We Think: A New View of Intelligence*, MIT Press, 2006.
8. Marco Dorigo and Thomas Stützle, *Ant Colony Optimization*, MIT Press, 2004.
9. Simon Haykin, *Neural Networks and Learning Machines*, 3rd Edition, Pearson Education, 2009.
10. Kevin M. Passino, *Biomimicry for Optimization, Control, and Automation*, Springer, 2005.
11. Steven M. LaValle, *Planning Algorithms*, Cambridge University Press, 2006.
12. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, MIT Press, 2016.
13. Russell C. Eberhart, Yuhui Shi, and James Kennedy, *Swarm Intelligence*, Morgan Kaufmann, 2001.

Course Code 333	AGENTIC AI for Robotics (Program Elective – V)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

1. Understand the principles, architectures, and components of Agentic AI for autonomous robotic systems.
2. Learn planning, reasoning, memory, and decision-making techniques for intelligent robotic agents.
3. Apply Agentic AI concepts to mobile robots, manipulators, UAVs, and collaborative robots.
4. Design autonomous robotic systems capable of adaptive task execution in dynamic environments.
5. Evaluate safety, ethical, and societal aspects of Agentic AI-enabled robotic systems.

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

1. Explain the concepts, architectures and operational principles of Agentic AI in autonomous robotic systems.
2. Apply planning, reasoning and decision-making techniques for intelligent robotic agents.
3. Design autonomous robotic systems capable of adaptive task execution in dynamic environments.
4. Analyze multi-agent robotic systems for collaborative industrial and service applications.
5. Evaluate safety, ethical, reliability and governance aspects of Agentic AI-enabled robotic systems.

UNIT – I Introduction to Agentic AI and Intelligent Robotic Agents

Introduction to Artificial Intelligence in Robotics; Evolution of autonomous robotic systems; Agentic AI concepts; Characteristics of intelligent agents; Agent architectures – Reactive, Deliberative, Hybrid and Learning Agents; Goal-based and Utility-based agents; Embodied intelligence; Cognitive robotics; Levels of robot autonomy; Environment representation; Agent perception-action cycle; Applications of Agentic AI in robotics.

UNIT – II Planning, Reasoning and Decision Making

Task planning in robotics; State-space search; Goal-Oriented Action Planning (GOAP); Behaviour Trees; Finite State Machines; Hierarchical Task Networks (HTN); Knowledge representation; World models; Context awareness; Short-term and long-term memory; Decision making under uncertainty; Adaptive planning; Failure recovery and replanning.

UNIT – III Agentic AI for Autonomous Robotic Systems

Perception-driven autonomous decision making; Robot perception and sensor fusion; Human-robot interaction; Tool use by robotic agents; Autonomous navigation and exploration; Intelligent robotic manipulation; Adaptive task execution; Learning from demonstrations; Intelligent warehouse robots; Service robots; Industrial autonomous robots; Humanoid robotic applications.

UNIT – IV Multi-Agent Robotics and Collaborative Systems

Introduction to multi-agent systems; Cooperative robotics; Distributed decision making; Multi-robot coordination; Swarm robotics; Task allocation; Robot communication; Fleet management; Cloud robotics; Edge intelligence; Collaborative robots (Cobots); Smart manufacturing; Applications in logistics, healthcare, agriculture and inspection robotics.

UNIT – V Safe and Responsible Agentic AI

Explainable AI (XAI); Responsible AI; Functional safety in autonomous robotic systems; Risk assessment; Human supervision; Trustworthy AI; Cybersecurity for robotic systems; Ethical issues in autonomous robotics; AI governance; Performance evaluation of autonomous agents; Future trends in Agentic AI and intelligent robotics.

Suggested Readings

1. Russell, S. J. and Norvig, P., **Artificial Intelligence: A Modern Approach**, 4th Edition, Pearson, 2021.
2. Lynch, K. M. and Park, F. C., **Modern Robotics: Mechanics, Planning, and Control**, Cambridge University Press, 2017.
3. Corke, P., **Robotics, Vision and Control: Fundamental Algorithms in MATLAB® and Python**, 3rd Edition, Springer, 2023.
4. Sutton, R. S. and Barto, A. G., **Reinforcement Learning: An Introduction**, 2nd Edition, MIT Press, 2018.
5. Murphy, K. P., **Machine Learning: A Probabilistic Perspective**, MIT Press, 2012.
6. Goodfellow, I., Bengio, Y. and Courville, A., **Deep Learning**, MIT Press, 2016.
7. Siciliano, B. and Khatib, O. (Eds.), **Springer Handbook of Robotics**, 2nd Edition, Springer, 2016.
8. Spong, M. W., Hutchinson, S. and Vidyasagar, M., **Robot Modeling and Control**, 2nd Edition, Wiley, 2020.

Course Code 334	Multi-Sensor Fusion and State Estimation (Program Elective – V)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

1. Understand the principles of multi-sensor fusion and state estimation in robotic systems.
2. Learn mathematical models for probabilistic state estimation and uncertainty representation.
3. Apply filtering and estimation techniques for robot localization, mapping, and navigation.
4. Integrate information from multiple sensors for robust perception in dynamic environments.
5. Evaluate sensor fusion techniques for autonomous robots and intelligent transportation systems.

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

1. Explain the principles of multi-sensor fusion and probabilistic state estimation used in robotic systems.
2. Apply Kalman filtering and Bayesian estimation techniques for robot localization and navigation.
3. Develop localization and mapping solutions using multiple sensing modalities.
4. Analyze and implement multi-sensor fusion techniques for autonomous robotic applications.
5. Evaluate advanced sensor fusion strategies for intelligent robotic systems operating in uncertain environments.

UNIT-I Fundamentals of Sensor Fusion

Introduction to robotic sensing; Types of sensors used in robotics; Coordinate frames and transformations; Sensor characteristics; Measurement models; Sensor calibration; Sources of uncertainty; Error propagation; Probabilistic robotics; Bayesian inference; Data fusion architectures; Levels of sensor fusion; Applications in autonomous robotic systems.

UNIT-II State Estimation Techniques

Robot state representation; Motion models; Observation models; Bayesian estimation; Recursive Bayesian filtering; Kalman Filter; Extended Kalman Filter (EKF); Unscented Kalman Filter (UKF); Complementary Filter; Performance comparison of estimation methods.

UNIT-III Localization and Mapping

Robot localization; Dead reckoning; Odometry; Inertial navigation; GPS/GNSS localization; Landmark-based localization; Monte Carlo Localization (Particle Filter); Simultaneous Localization and Mapping (SLAM); Visual SLAM; LiDAR SLAM; Loop closure; Map representation.

UNIT-IV Multi-Sensor Fusion for Autonomous Robots

Fusion of IMU, LiDAR, Camera, GPS and Wheel Encoder data; Visual-Inertial Odometry (VIO); Sensor synchronization; Data association; Object tracking; Environment perception; Navigation in dynamic environments; Autonomous vehicles; Mobile robots; UAV navigation; Industrial robotic applications.

UNIT-V Advanced Applications and Emerging Trends

State estimation for manipulators; Human motion tracking; Collaborative robots; Multi-robot localization; Sensor fusion in intelligent manufacturing; Fault detection and diagnosis; Sensor redundancy; Artificial Intelligence for sensor fusion; Digital twins; Edge AI; Future trends in autonomous robotic perception.

Suggested Text Books

1. Thrun, S., Burgard, W. and Fox, D., **Probabilistic Robotics**, MIT Press, 2005.
2. Corke, P., **Robotics, Vision and Control: Fundamental Algorithms in MATLAB® and Python**, 3rd Edition, Springer, 2023.
3. Bar-Shalom, Y., Li, X. R. and Kirubarajan, T., **Estimation with Applications to Tracking and Navigation**, Wiley, 2001.
4. Lynch, K. M. and Park, F. C., **Modern Robotics: Mechanics, Planning, and Control**, Cambridge University Press, 2017.
5. Siciliano, B. and Khatib, O. (Eds.), **Springer Handbook of Robotics**, 2nd Edition, Springer, 2016.
6. Maybeck, P. S., **Stochastic Models, Estimation and Control**, Academic Press.
7. Grewal, M. S. and Andrews, A. P., **Kalman Filtering: Theory and Practice with MATLAB**, 5th Edition, Wiley.
8. Farrell, J. A., **Aided Navigation: GPS with High Rate Sensors**, McGraw-Hill.

Course Code ME 335	DIGITAL TWIN ENGINEERING FOR ROBOTICS AND SMART SYSTEMS (Program Elective – V)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Understand the principles and architecture of Digital Twin systems.
- Learn modeling and simulation techniques for physical assets and robotic systems.
- Study real-time data integration, monitoring and predictive analytics.
- Develop Digital Twins for manufacturing, robotics and autonomous systems.
- Apply AI and IoT technologies for intelligent Digital Twin applications.

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

1. Explain Digital Twin concepts and Cyber-Physical Systems architecture.
2. Develop virtual models of engineering and robotic systems.
3. Integrate sensor data and IoT technologies with Digital Twin platforms.
4. Apply simulation and predictive analytics for system monitoring and optimization.
5. Design Digital Twin solutions for robotics, manufacturing and autonomous systems.

UNIT – I Fundamentals of Digital Twins

Introduction to Digital Twins, evolution of Digital Twin technology, digital thread concept, Cyber-Physical Systems, Digital Twin architecture, components of Digital Twins, data acquisition and synchronization, Digital Twin lifecycle, applications in manufacturing, robotics, aerospace, healthcare and smart cities.

UNIT – II Modeling and Simulation for Digital Twins

Physical system modeling, mathematical modeling, CAD-based models, physics-based simulation, multibody simulation, discrete-event simulation, finite element models, virtual commissioning, real-time simulation, Digital Twin development workflow.

UNIT – III IoT and Data Integration

Industrial IoT architecture, sensors and data acquisition systems, communication protocols, cloud platforms, edge computing, OPC-UA, MQTT, real-time data streaming, database systems, data synchronization, interoperability and integration of physical and virtual systems.

UNIT – IV Digital Twins for Robotics and Autonomous Systems

Robot Digital Twins, virtual robot commissioning, robotic work-cell simulation, robot trajectory verification, ROS2 integration, digital twins for mobile robots, drones and autonomous systems, predictive maintenance, condition monitoring, human-robot collaboration and virtual testing environments.

UNIT – V AI-Driven Digital Twins and Industrial Applications

Machine learning for Digital Twins, predictive analytics, anomaly detection, reinforcement learning for system optimization, Digital Twins in smart manufacturing, Industry 4.0 integration, autonomous factories, sustainability assessment, cybersecurity challenges, future trends and industrial case studies.

Software / Tools Required

MATLAB & Simulink (Simscape Multibody), ROS2 (Robot Operating System), Gazebo / Ignition Gazebo Simulator, NVIDIA Isaac Sim, Siemens Simcenter Amesim, MSC ADAMS, RecurDyn, Python (NumPy, SciPy, Pandas, Matplotlib), Node-RED, MQTT Broker (Mosquitto), OPC UA, ThingSpeak / AWS IoT / Azure Digital Twins, Docker, Git & GitHub

Illustrative Case Studies

- Digital Twin of an industrial robotic manipulator
- Virtual commissioning of a robotic assembly line
- Predictive maintenance of industrial robots using Digital Twins
- Digital Twin for autonomous mobile robot (AMR) navigation
- Smart manufacturing using IoT-enabled Digital Twins
- Real-time monitoring of CNC machines using Digital Twin technology
- Digital Twin for drone mission planning and monitoring
- AI-driven Digital Twin for warehouse automation

NPTEL / SWAYAM Online Resources

- nptel.ac.in/courses/112105249 (Robotics, IIT Kharagpur)
- nptel.ac.in/courses/107106090 (Introduction To Robotics, IIT Madras)

Professional Resources

- Siemens Digital Twin Documentation
- Azure Digital Twins Documentation
- AWS IoT TwinMaker Documentation
- MATLAB Simscape Documentation
- ROS2 Official Documentation
- NVIDIA Isaac Sim Documentation
- MQTT Official Documentation
- OPC Foundation Documentation
- IEEE Digital Twin Initiative
- GitHub Digital Twin Projects

Suggested Learning Activities

- Develop a Digital Twin of a robotic manipulator using MATLAB Simscape or Gazebo.
- Integrate IoT sensors with a Digital Twin using MQTT or OPC UA protocols.
- Simulate robotic systems using ROS2 and NVIDIA Isaac Sim.
- Perform virtual commissioning of a robotic workcell.
- Develop predictive maintenance models using machine learning and sensor data.
- Build a cloud-connected Digital Twin using AWS IoT or Azure Digital Twins.
- Analyze real-time sensor data for system monitoring and anomaly detection.
- Study Industry 4.0 applications of Digital Twins in manufacturing and robotics.

- Review IEEE research papers on Digital Twin technologies for robotics and smart systems.
- Complete a mini-project on designing a Digital Twin for an autonomous robot or smart manufacturing system with real-time monitoring and predictive analytics.

Suggested Text Books

1. Fei Tao and Qinglin Qi, *Digital Twin Driven Smart Manufacturing*, Academic Press (Elsevier), 2019.
2. Michael Grieves and John Vickers, *Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems*, in *Transdisciplinary Perspectives on Complex Systems*, Springer, 2017.
3. Shyam Varan Nath, *Industrial IoT and Digital Twins: Managing and Monitoring Industrial Assets*, Packt Publishing, 2021.
4. Mikell P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, 5th Edition, Pearson, 2020.
5. Rajkumar Buyya and Amir Vahid Dastjerdi (Eds.), *Internet of Things: Principles and Paradigms*, Elsevier (Morgan Kaufmann), 2016.
6. Bruno Siciliano and Oussama Khatib (Eds.), *Springer Handbook of Robotics*, 2nd Edition, Springer, 2016.
7. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, 2018.
8. Peter Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB® and Python*, 3rd Edition, Springer, 2023.

Course Code OE 941	BUSINESS ANALYTICS (OPEN ELECTIVE)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Objectives:

- Understanding the basic concepts of business analytics and applications
- Study various business analytics methods including predictive, prescriptive and descriptive analytics
- Prepare the students to model business data using various data mining, decision making methods

Outcomes: Upon completing this course, students will be able to:

1. To understand the basic concepts of business analytics
2. Identify the application of business analytics and use tools to analyze business data
3. Become familiar with various metrics, measures used in business analytics
4. Illustrate various descriptive, predictive and prescriptive methods and techniques
5. Model the business data using various business analytical methods and techniques

UNIT-I

Introduction to Business Analytics: Introduction to Business Analytics, need and science of data driven (DD) decision making, Descriptive, predictive, prescriptive analytics and techniques, Big data analytics, Web and Social media analytics, Machine Learning algorithms, framework for decision making, challenges in DD decision making and future.

UNIT-II

Descriptive Analytics: Introduction, data types and scales, types of measurement scales, population and samples, measures of central tendency, percentile, decile and quartile, measures of variation, measures of shape-skewness, data visualization

UNIT-III

Forecasting Techniques: Introduction, time-series data and components, forecasting accuracy, moving average method, single exponential smoothing, Holt's method, Holt-Winter model, Croston's forecasting method, regression model for forecasting, Auto regression models, auto-regressive moving process, ARIMA, Theil's coefficient

UNIT-IV

Decision Trees: CHAID, Classification and Regression tree, splitting criteria, Ensemble and method and random forest. **Clustering:** Distance and similarity measures used in clustering, Clustering algorithms, K-Means and Hierarchical algorithms, **Prescriptive Analytics-** Linear Programming(LP) and LP model building,

UNIT-V

Six Sigma: Introduction, introduction, origin, 3-Sigma Vs Six-Sigma process, cost of poor quality, sigma score, industry applications, six sigma measures, DPMO, yield, sigma score, DMAIC methodology, Six Sigma toolbox

Suggested Reading:

1. Dinesh Kumar, *Data Analytics*, 1st Edition, Wiley India, 2017.

2. Marc J. Schniederjans, Dara G. Schniederjans, and Christopher M. Starkey, *Business Analytics: Principles, Concepts, and Applications with SAS*, Pearson, 2015.
3. S. Christian Albright and Wayne L. Winston, *Business Analytics: Data Analysis and Decision Making*, 7th Edition, Cengage Learning, 2023.

Web Resources:

1. <https://onlinecourses.nptel.ac.in/noc18-mg11/preview>
2. <https://nptel.ac.in/courses/110105089/>

Course Code OE 942	INDUSTRIAL SAFETY (OPEN ELECTIVE)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives:

- Causes for industrial accidents and preventive steps to be taken.
- Fundamental concepts of Maintenance Engineering.
- About wear and corrosion along with preventive steps to be taken
- The basic concepts and importance of fault tracing.
- The steps involved in carrying out periodic and preventive maintenance of various equipments used in industry

Course Outcomes:

1. Identify the causes for industrial accidents and suggest preventive measures.
2. Identify the basic tools and requirements of different maintenance procedures.
3. Apply different techniques to reduce and prevent Wear and corrosion in Industry.
4. Identify different types of faults present in various equipments like machine tools, IC Engines, boilers etc.
5. Apply periodic and preventive maintenance techniques as required for industrial equipments like motors, pumps and air compressors and machine tools etc

UNIT-I

Industrial safety: Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes, Fire prevention and firefighting, equipment and methods.

UNIT-II

Fundamentals of Maintenance Engineering: Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

UNIT-III

Wear and Corrosion and their Prevention: Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications of Screw down grease cup, Pressure grease gun, Splash lubrication, Gravity lubrication, Wick feed lubrication, Side feed lubrication, Ring lubrication, Definition of corrosion, principle and factors affecting the corrosion, Types of corrosion, corrosion prevention methods.

UNIT–IV

Fault Tracing: Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, any one machine tool, Pump, Air compressor, Internal combustion engine, Boiler, Electrical motors, Types of faults in machine tools and their general causes.

UNIT–V

Periodic and Preventive Maintenance: Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of Machine tools, Pumps, Air compressors, Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance

Suggested Reading:

1. H. P. Garg, *Maintenance Engineering*, 2nd Edition, S. Chand Publishing, 2017.
2. Audel (Rex Miller and Mark R. Miller), *Audel Pumps and Hydraulics*, 8th Edition, Wiley, 2017.
3. Lindy Higgins and R. Keith Mobley (Eds.), *Maintenance Engineering Handbook*, 8th Edition, McGraw-Hill Education, 2019.
4. Hans F. Winterkorn and Hsai-Yang Fang (Eds.), *Foundation Engineering Handbook*, 2nd Edition, Springer, 1991.

Course Code OE 943	OPERATION RESEARCH (OPEN ELECTIVE)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives:

- *Introduce the concepts of optimization techniques*
- *Formulation of LPP models*
- *Basic concepts of Non-linear programming, Dynamic programming, Game theory are introduced.*

Course Outcomes: Upon completing this course, students will be able to:

1. *To apply the dynamic programming to solve problems of discrete and continuous variables.*
2. *Apply the concepts of non-linear programming*
3. *Carry out sensitivity analysis*
4. *Model the real world problems and simulate it.*
5. *Apply graph theory, competitive models, and game theory simulations.*

UNIT I

Optimization Techniques, Model Formulation, models, General L.R Formulation, Simplex Techniques, Sensitivity Analysis, Inventory Control Models

UNIT II

Formulation of a LPP - Graphical solution revised simplex method - duality theory - dual simplex method - sensitivity analysis - parametric programming

UNIT III:

Nonlinear programming problem - Kuhn-Tucker conditions min cost flow problem - max flow problem - CPM/PERT

UNIT IV

Scheduling and sequencing - single server and multiple server models deterministic inventory models - Probabilistic inventory control models - Geometric Programming.

UNIT V

1. Hamdy A. Taha, *Operations Research: An Introduction*, 10th Edition, Pearson, 2017.
2. Harvey M. Wagner, *Principles of Operations Research: With Applications to Managerial Decisions*, 2nd Edition, Prentice Hall of India, 2009 (Indian Reprint).
3. J. C. Pant, *Introduction to Optimisation: Operations Research*, Jain Brothers, 2008.
4. Frederick S. Hillier and Gerald J. Lieberman, *Introduction to Operations Research*, 11th Edition, McGraw-Hill Education, 2021.
5. P. (Panneerselvam) Panneerselvam, *Operations Research*, 3rd Edition, PHI Learning Pvt. Ltd., 2024.

Course Code OE 944	COST MANAGEMENT OF ENGINEERING PROJECTS (OPEN ELECTIVE)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Objectives:

- Introduce the concepts of cost management, inventory valuation , decision making
- Fundamentals of cost overruns, project execution and technical activities
- Introduce the concepts of Quantitative techniques for cost management, Linear Programming, PERT/CPM

Outcomes:

1. Understanding of strategic cost management process, control of cost and decision making based on the cost of the project.
2. Ability to appreciate detailed engineering activities of the project and execution of projects
3. Preparation of project report and network diagram
4. Able to plan Cost Behavior , Profit Planning , Enterprise Resource Planning, Total Quality Management.
5. Applications of various quantitative techniques for cost management

UNIT I

Introduction and Overview of the Strategic Cost Management Process-Cost concepts in decision-making; relevant cost, Differential cost, Incremental cost and Opportunity cost. Objectives of a Costing System- Inventory valuation- Creation of a Database for operational control; Provision of data for Decision-Making.

UNIT II

Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning- Project execution as conglomeration of technical and non- technical activities- Detailed Engineering activities.

UNIT III

Pre project execution main clearances and documents Project team: Role of each member. Importance Project site: Data required with significance. Project contracts. Types and contents. Project execution Project cost control. Bar charts and Network diagram. Project commissioning: mechanical and process

UNIT IV

Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis. Various decision-making problems- Standard Costing and Variance Analysis. Pricing strategies: Pareto Analysis. Target costing, Life Cycle Costing. Costing of service sector- Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Total Quality Management and Theory of constraints- Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis. Budgetary Control; Flexible Budgets- Performance budgets- Zero-based budgets. Measurement of Divisional profitability pricing decisions including transfer pricing.

UNIT V

Quantitative techniques for cost management, Linear Programming, PERT/CPM,-
Transportation problems, Assignment problems, Simulation, Learning Curve Theory.

Suggested Reading :

1. Srikant M. Datar and Madhav V. Rajan, *Horngren's Cost Accounting: A Managerial Emphasis*, 17th Edition, Pearson, 2021.
2. Charles T. Horngren and George Foster, *Advanced Management Accounting*, 6th Edition, Pearson Education, 2008.
3. Robert S. Kaplan and Anthony A. Atkinson, *Advanced Management Accounting*, 3rd Edition, Pearson Education, 1998.
4. Ashish K. Bhattacharyya, *Principles and Practices of Cost Accounting*, 5th Edition, PHI Learning Pvt. Ltd., 2019.
5. N. D. Vohra, *Quantitative Techniques in Management*, 6th Edition, McGraw Hill Education (India), 2017.

Course Code OE 942 ME	ADVANCED MATERIALS (Open Elective)						Course Type OE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
		3	-	-	3	40	60

Course Objectives

- Understand the structure and properties of modern functional materials.
- Identify advanced materials used in infrastructure, healthcare, electronics, energy, and digital technologies.
- Explain smart and sustainable material systems.
- Evaluate material choices for interdisciplinary engineering applications.
- Appreciate emerging trends such as nanomaterials, biomaterials, and semiconductor materials.

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

CO's	Description	Blooms Level
C01	Explain the classification, properties, and applications of advanced engineering materials..	L2
C02	Describe the characteristics and applications of smart materials used in modern engineering systems	L2
C03	Explain the properties and applications of biomaterials and nanomaterials in healthcare and other engineering fields.	L3
C04	Analyze the use of advanced materials in electronics, electrical systems, energy storage, and computing technologies..	L4
C05	Evaluate sustainable materials for civil, mining, and environmental engineering applications based on performance and sustainability	L4

UNIT I – Fundamentals of Advanced Materials: Classification of engineering materials. Structure–property relationship. Crystalline, amorphous, and nanostructured materials. Electrical, thermal, optical, and magnetic properties. Surface properties and coatings. Material selection for multidisciplinary applications.

UNIT II – Smart Materials and Intelligent Infrastructure: Introduction to smart materials., Shape memory materials (concept only)., Piezoelectric materials., Electrochromic and thermochromic materials. Self-healing materials., Phase change materials for thermal energy storage., Smart concrete and smart coatings. Sensor-integrated infrastructure materials.

UNIT III – Biomaterials and Nanomaterials : Introduction to biomaterials., Metallic, ceramic, polymeric, and composite biomaterials. Biocompatibility and bioactivity. Orthopedic and dental materials. Tissue engineering scaffolds. Nanomaterials: graphene, carbon nanotubes, nanoparticles, quantum dots.Environmental and health aspects of nanomaterials.

UNIT IV – Materials for Electronics, Electrical and Computing Technologies : Semiconductor materials: Si, GaN, SiC., Dielectric and insulating materials., Conductive polymers., Flexible electronic materials. Materials for sensors and MEMS., Battery materials., Supercapacitor materials., Thermal management materials for electronics., Materials used in AI hardware and data centers.

UNIT V – Sustainable Materials for Civil and Mining Engineering: Geopolymer concrete., Recycled aggregates and industrial waste utilization. Fiber-reinforced cementitious materials. Corrosion-resistant materials for infrastructure. , Geosynthetics., Materials for mine support and underground construction.

Suggested Text Books

1. Callister, W. D., Jr., & Rethwisch, D. G. (2024). *Materials Science and Engineering: An Introduction* (11th Edition). John Wiley & Sons, Hoboken, NJ, USA.
2. Ashby, M. F. (2024). *Materials and Sustainable Development* (3rd Edition). Butterworth-Heinemann (Elsevier), Oxford, UK.
3. Ratner, B. D., Hoffman, A. S., Schoen, F. J., & Lemons, J. E. (Editors). (2020). *Biomaterials Science: An Introduction to Materials in Medicine* (4th Edition). Academic Press (Elsevier), Cambridge, MA, USA.
4. Shackelford, J. F. (2021). *Introduction to Materials Science for Engineers* (9th Edition). Pearson Education, New York, USA.
5. Poole, C. P., Jr., & Owens, F. J. (2022). *Introduction to Nanotechnology* (2nd Edition, Reprint). John Wiley & Sons, Hoboken, NJ, USA.

Course Code OE 946	WASTE TO ENERGY (OPEN ELECTIVE)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Objectives:

- To know the various forms of waste
- To understand the processes of Biomass Pyrolysis.
- To learn the technique of Biomass Combustion.

Outcomes: Upon completing this course, students will be able to:

1. Understand the concept of conservation of waste.
2. Identify the different forms of wastage.
3. Chose the best way for conservation to produce energy from waste.
4. Explore the ways and means of combustion of biomass.
5. Develop a healthy environment for the mankind.

UNIT-I:

Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

UNIT-II:

Biomass Pyrolysis: Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

UNIT-III:

Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

UNIT-IV:

Biomass Combustion: Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

UNIT-V:

Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass Bio diesel production - Urban waste to energy conversion - Biomass energy programme in India.

Suggested Reading:

1. Ashok V. Desai, *Non-Conventional Energy*, 2nd Edition, Wiley Eastern Ltd. (New Age International Reprint), 2014.
2. K. C. Khandelwal and S. S. Mahdi, *Biogas Technology: A Practical Handbook*, Vols. I & II, Tata McGraw-Hill Publishing Co., 1986 (Latest available edition/reprint).
3. D. S. Chahal (Ed.), *Food, Feed and Fuel from Biomass*, Oxford & IBH Publishing Co. Pvt. Ltd., 1991.
4. C. Y. WereKo-Brobby and E. B. Hagan, *Biomass Conversion and Technology*, John Wiley & Sons, 1996.

Course Code OE 947	INTERNET OF THINGS (Open Elective)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives:

- To understand the concepts of Internet of Things and able to build IoT applications
- To learn the programming and use of Arduino and Raspberry Pi boards.
- To know about data handling and analytics in SDN.

Course Outcomes:

After Completion of the course Student will be able to:

1. Known basic protocols in sensor networks.
2. Program and configure Arduino boards for various designs.
3. Python programming and interfacing for Raspberry Pi.
4. Design IoT applications in different domains.

UNIT – I

Introduction to Internet of Things, Characteristics of IoT, Physical design of IoT, Functional blocks of IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks.

UNIT – II

Machine-to-Machine Communications, Difference between IoT and M2M, Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino,

UNIT – III

Introduction to Python programming, Introduction to Raspberry Pi, Interfacing Raspberry Pi with basic peripherals, Implementation of IoT with Raspberry Pi

UNIT - IV

Implementation of IoT with Raspberry Pi, Introduction to Software defined Network (SDN), SDN for IoT, Data Handling and Analytics,

UNIT - V

Cloud Computing, Sensor-Cloud, Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring

Suggested Readings:

1. Pethuru Raj and Anupama C. Raman, *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC Press, 2017.
2. Tero Karvinen, Kimmo Karvinen, and Ville Valtokari, *Make: Sensors – A Hands-On Primer for Monitoring the Real World with Arduino and Raspberry Pi*, 1st Edition, Maker Media, 2014.
3. Arshdeep Bahga and Vijay Madisetti, *Internet of Things: A Hands-on Approach*, Universities Press, 2015.
4. Vijay Madisetti and Arshdeep Bahga, *Internet of Things: A Hands-on Approach*, Universities Press, 2015.
5. Waltenegus Dargie and Christian Poellabauer, *Fundamentals of Wireless Sensor Networks: Theory and Practice*, 2nd Edition, Wiley, 2022.
6. Charles Bell, *Beginning Sensor Networks with Arduino and Raspberry Pi*, Apress, 2013.

Course Code OE 948	CYBER SECURITY (Open Elective)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	3	-	-	3	40	60	3

Course Objectives

- Learn the various threats in networks and security concepts.
- Apply authentication applications in different networks.
- Understand security services for email.
- Awareness of firewall and IT laws and policies

Course Outcomes:

After completion of this course, the students shall be able to:

1. Understand the various network threats.
2. Analyze the forensic tools for evidence collection.
3. Apply the firewalls for threat analysis.

UNIT-I

Ethical hacking, Attack Vectors, Cyberspace and Criminal Behaviour, Clarification of Terms, Traditional Problems associated with Computer Crimes, Realms of Cyber world, brief history of the internet, contaminants and destruction of data, unauthorized access, computer intrusions, white-collar crimes, viruses and malicious code, virus attacks, pornography, software piracy, mail bombs, exploitation, stalking and obscenity in internet, Cyber psychology, Social Engineering.

UNIT-II

Introduction to Digital forensics, Forensic software and handling, forensic hardware and handling, analysis and advanced tools, forensic technology and practices, Biometrics: face, iris and fingerprint recognition, Audio-video evidence collection, Preservation and Forensic Analysis.

UNIT-III

Investigation Tools, e-discovery, EDRM Models, digital evidence collection and preservation, email investigation, email tracking, IP tracking, email recovery, search and seizure of computer systems, password cracking.

UNIT-IV

Forensic Analysis of OS artifact, Internet Artifacts, File System Artifacts, Registry Artifacts, Application Artifacts, Report Writing, Mobile Forensic- identification, collection and preservation of mobile evidences, social media analysis, data retrieval, Email analysis from mobile phones.

UNIT-V

Ethics, Policies and IT Act Basics of Law and Technology, Introduction to Indian Laws, Scope and Jurisprudence, Digital Signatures, E Commerce-an Introduction, possible crime scenarios, law coverage, data interchange, mobile communication development, smart card and expert systems Indian Laws, Information Technology Act 2000, Indian Evidence Act, India Technology Amendment Act 2008, Indian Penal Code , Computer Security Act 1987, National Information Infrastructure Protection Act 1996, Fraud Act 1997, Children Online Protection Act 1998, Computer Fraud and Abuse Act 2001, Intellectual Property, IP Theft, Copyright, Trademark, Privacy and Censorship, Introduction to Cyber Ethics, rights over intellectual property, Corporate IT Policy Formulations, Compliance Auditing.

Suggested Readings

1. Charles P. Pfleeger and Shari Lawrence Pfleeger, *Security in Computing*, 5th Edition, Pearson, 2015.
2. Behrouz A. Forouzan and Debdeep Mukhopadhyay, *Cryptography and Network Security*, 4th Edition, McGraw Hill Education (India), 2015.
3. William Stallings, *Cryptography and Network Security: Principles and Practice*, 8th Edition, Pearson, 2023.
4. Charlie Kaufman, Radia Perlman, and Mike Speciner, *Network Security: Private Communication in a Public World*, 2nd Edition, Pearson, 2002.
5. Neal Krawetz, *Introduction to Network Security*, Thomson Course Technology, 2007.
6. Bruce Schneier, *Applied Cryptography: Protocols, Algorithms, and Source Code in C*, 20th Anniversary Edition, Wiley, 2015.

Course Code ME 353	Robotics Simulation and Computational Laboratory						CourseType Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	-	-	2	2	50	-	1

Course Objectives

1. Develop computational models for robotic and automation systems using MATLAB, Simulink, and Python.
2. Apply numerical methods, optimization techniques, and intelligent algorithms to solve engineering problems in robotics.
3. Analyze, simulate, and visualize robotic systems using modern computational tools.

Course Outcomes

1. Develop MATLAB, Simulink, and Python programs for modeling and simulation of robotic systems.
2. Apply optimization, machine learning, and numerical techniques to engineering problems.
3. Analyze and interpret computational results for robotics and automation applications.

Module I – MATLAB Programming (6)

1. MATLAB programming fundamentals and matrix operations.
2. Data visualization using 2D and 3D plots.
3. Numerical solution of linear and nonlinear equations.
4. Curve fitting and interpolation.
5. Numerical solution of ordinary differential equations.
6. Data analysis and visualization.

Module II – Simulink and Control (5)

7. Introduction to Simulink.
8. Modeling of first- and second-order systems.
9. PID controller design using Simulink.
10. Modeling and simulation of DC motor speed control.
11. Robotic actuator control using Simulink.

Module III – Robotics Applications (5)

12. Forward kinematics of a 2R manipulator.
13. Inverse kinematics of a 2R manipulator.
14. Trajectory planning of a robotic manipulator.
15. Workspace analysis of a robotic arm.
16. Robot dynamics simulation using Robotics Toolbox.

Module IV – Python for Robotics (4)

17. Numerical computing using NumPy and SciPy.
18. Data visualization using Matplotlib.
19. Image processing using OpenCV.
20. Machine learning application using Scikit-learn for robotic data

*Students are advised to do any 10 experiments

Course Code ME 352	Robotic Drives and Control Systems Laboratory						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	-	-	2		50	-	
				2			1

Course Objectives The student will be able to

1. Develop embedded applications by interfacing sensors, actuators, and peripheral devices with modern microcontroller platforms.
2. Design hydraulic, pneumatic, and electro-pneumatic control circuits for industrial automation.
3. Analyze and implement embedded control solutions for robotic and automation applications.

Course Objectives After successful completion of the laboratory, student will be able to

1. Develop embedded applications using sensors, actuators, and microcontrollers.
2. Design and implement hydraulic, pneumatic, and electro-pneumatic automation circuits.
3. Integrate embedded hardware and control systems for industrial automation and robotic applications.

Module I – Sensors (4)

1. Sensor calibration
2. Position and speed measurement
3. Temperature and pressure measurement
4. Force and strain measurement

Module II – Embedded Systems (6)

5. LCD interfacing
6. PWM control of DC motor
7. Servo motor control
8. ADC/DAC interfacing
9. Temperature monitoring
10. Ultrasonic sensor interfacing

Module III – Automation Systems (6)

13. Hydraulic speed control
14. Pneumatic cylinder control
15. Electro-pneumatic sequencing
16. Electro-hydraulic control
17. PLC-based automation
18. Mini automation system
19. Mini automation project

Module IV – 8051 Experiments

- 20. LED/LCD interfacing
- 21. DC motor control

Module V – Vision Systems

- 22. Camera calibration and image acquisition
- 23. Object detection and classification
- 24. Feature extraction and dimensional measurement
- 25. Vision-guided robotic pick-and-place simulation

A student has to perform atleast 12 experiments in a semester.

Course Code ME 371	MINI PROJECT						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	4	-	-		50		2

Course Objectives:

- Understand the purpose of doing mini project
- Learn the resources available at the college and outside for pursuing project
- Importance of literature review
- Learn to select appropriate software and procedure
- Learn to document results and arrive at required conclusions

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

1. Identify engineering problems reviewing available literature
2. Study different techniques used to analyze complex systems.
3. Use related techniques and software's for solving the problem
4. Interpret the results and arrive at the relevant conclusions.
5. Document the findings as a technical report with proper references

Guidelines

1. Guide allocation will be done at the beginning of the semester. Identification of mini project work will be done with Guides consultation
2. Mini project presentation should be done along with the report on identification of topic for the work and the methodology adopted involving scientific research, collection and analysis of data, determining solutions highlighting individuals' contribution.
3. Evaluation of Mini project will be done by the Departmental Committee. Half of the marks are awarded by the Guide and the remaining half of the marks will be awarded by Departmental Committee.

Course Code AC 001	RESEARCH METHODOLOGY AND IPR (AUDIT COURSE-I)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	2	-	-	3	40	60	0

Course Objectives:

- Learn to focus on research related activities.
- Learn methods to devise and develop the various research designs
- Learn basic principles of data collection and analysis techniques
- Learn the style and format of writing a report for technical papers

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

1. Motivate the orientation towards research related activities
2. Formulate the research problem, analyze research related information
3. Identify various sources for literature review and design an experimentation set-up
4. Apply the basic principles of data collection and analysis techniques
5. Improve the style and format of writing a report for technical / Journal articles

UNIT – I

Research Methodology: Objectives and Motivation of Research, Types of Research, Research Approaches, Significance of Research, Research Methods verses Methodology, Research and Scientific Method, Important of Research Methodology, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India, Benefits to the society in general.

Defining the Research Problem: Definition of Research Problem, Problem Formulation, Necessity of Defining the Problem, Technique involved in Defining a Problem.

UNIT – II

Literature Survey: Importance of Literature Survey, Sources of Information, Assessment of Quality of Journals and Articles, Information through Internet. **Literature Review:** Need of Review, Guidelines for Review, Record of Research Review.

UNIT – III

Research Design: Meaning of Research Design, Need of Research Design, Feature of a Good Design Important Concepts Related to Research Design, Different Research Designs, Basic Principles of Experimental Design, Developing a Research Plan, Design of Experimental Set-up, Use of Standards and Codes.

UNIT – IV

Data Collection: Collection of primary data, Secondary data, Data organization, Methods of data grouping, Diagrammatic representation of data, Graphic representation of data. Sample Design, Need for sampling, some important sampling definitions, Estimation of population, Role of Statistics for Data Analysis, Parametric V/s Non Parametric methods, Descriptive Statistics, Measures of central tendency and Dispersion, Hypothesis testing, Use of Statistical software.

Data Analysis: Deterministic and random data, Uncertainty analysis, Tests for significance: Chi-square, student's t-test, Regression modeling, Direct and Interaction effects, ANOVA, F-test, Time Series analysis, Autocorrelation and Autoregressive modeling.

UNIT – V

Research Report Writing: Format of the Research report, Synopsis, Dissertation, Thesis its Differentiation, References/Bibliography/Webliography, Technical paper writing/Journal report writing, making presentation, Use of visual aids. Research Proposal Preparation: Writing a Research Proposal and Research Report, Writing Research Grant Proposal.

Suggested Reading:

1. C. R. Kothari and Gaurav Garg, *Research Methodology: Methods and Techniques*, 4th Edition, New Age International Publishers, 2019.
2. R. Ganesan, *Research Methodology for Engineers*, 2nd Edition, MJP Publishers, 2017.
3. Ratan Khananabis and Suvasis Saha, *Research Methodology*, Universities Press, 2015.
4. Y. P. Aggarwal, *Statistical Methods: Concepts, Application and Computation*, Sterling Publishers Pvt. Ltd., 2014.
5. Vijay Upagade and Arvind Shende, *Research Methodology*, 2nd Edition, S. Chand Publishing, 2019.
6. G. Nageswara Rao, *Research Methodology and Quantitative Methods*, BS Publications, 2012.

Course Code AC 002	STRESS MANAGEMENT BY YOGA (AUDIT COURSE-II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	2	-	-	3	40	60	0

Objectives:

- *Creating awareness about different types of stress and the role of yoga in the management of stress.*
- *Promotion of positive health and overall wellbeing (Physical, mental, emotional, social and spiritual).*
- *Prevention of stress related health problems by yoga practice.*

Outcomes: Students will be able to

1. *To understand yoga and its benefits.*
2. *Enhance Physical strength and flexibility.*
3. *Learn to relax and focus.*
4. *Relieve physical and mental tension through Asanas*
5. *Improve work performance and efficiency.*

UNIT-I

Meaning and definition of Yoga - Historical perspective of Yoga - Principles of Astanga Yoga by Patanjali.

UNIT-II

Meaning and definition of Stress - Types of stress - Eustress and Distress. Anticipatory Anxiety and Intense Anxiety and depression. Meaning of Management- Stress Management.

UNIT-III

Concept of Stress according to Yoga - Stress assessment methods - Role of Asana, Pranayama and Meditation in the management of stress.

UNIT-IV

Asanas- (5 Asanas in each posture) - Warm up - Standing Asanas - Sitting Asanas - Prone Asanas - Supine asanas - Surya Namaskar

UNIT-V

Pranayama- Anulom and Vilom Pranayama - Nadishudhi Pranayama – Kapalabhati- Pranayama - Bhramari Pranayama - Nadanusandhana Pranayama.

Meditation techniques: Om Meditation - Cyclic meditation : Instant Relaxation technique (QRT), Quick Relaxation Technique (QRT), Deep Relaxation Technique (DRT).

Suggested Reading:

- Janardhan Swami Yogabhyasi Mandal, *Yogic Asanas for Group Training – Part I*, Janardhan Swami Yogabhyasi Mandal, Nagpur, Latest Edition (Reprint).
- Swami Vivekananda, *Raja Yoga (or Conquering the Internal Nature)*, Advaita Ashrama, Kolkata, Latest Edition (2023 Reprint).
- H. R. Nagendra and R. Nagarathna, *Yoga Perspective in Stress Management*, Swami Vivekananda Yoga Prakashana, Bengaluru, Latest Edition (2019 Reprint).

Online Resources:

https://onlinecourses.nptel.ac.in/noc16_ge04/preview

<https://freevidelectures.com/course/3539/indian-philosophy/11>

Course Code AC 003	PERSONALITY DEVELOPMENT THROUGH LIFE ENHANCEMENT SKILLS (AUDIT COURSE-II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	2	-	-		40	60	

Objectives :

- To learn to achieve the highest goal happily
- To become a person with stable mind, pleasing personality and determination
- To awaken wisdom in students

Outcomes: Upon completing this course, students will be able to:

1. Develop their personality and achieve their highest goal of life.
2. Lead the nation and mankind to peace and prosperity.
3. To practice emotional self regulation.
4. Develop a positive approach to work and duties.
5. Develop a versatile personality.

UNIT-I

Neetisatakam – Holistic development of personality - Verses 19, 20, 21, 22 (Wisdom) - Verses 29, 31, 32 (Pride and Heroism) - Verses 26, 28, 63, 65 (Virtue)

UNIT-II

Neetisatakam – Holistic development of personality (cont'd) - Verses 52, 53, 59 (don't's) - Verses 71, 73, 75 & 78 (do's) - Approach to day to day works and duties.

UNIT-III

Introduction to Bhagavad Geetha for Personality Development - Shrimad Bhagawad Geeta: Chapter 2 – Verses 41, 47, 48 - Chapter 3 – Verses 13, 21, 27, 35 - Chapter 6 – Verses 5, 13, 17, 23, 35 - Chapter 18 – Verses 45, 46, 48 Chapter – 6: Verses 5, 13, 17, 23, 35; Chapter – 18: Verses 45, 46, 48

UNIT-IV

Statements of basic knowledge - Shrimad Bhagawad Geeta: Chapter 2- Verses 56, 62, 68 - Chapter 12 – Verses 13, 14, 15, 16, 17, 18 - Personality of Role model from Shrimad Bhagawad Geeta.

UNIT-V

Role of Bhagavadgeeta in the present scenario - Chapter 2 – Verses 17 – Chapter 3 – Verses 36, 37, 42 - Chapter 4 – Verses 18, 38, 39 - Chapter 18 – Verses 37, 38, 63.

Suggested Reading:

- 1.. “Srimad Bhagavad Gita” by Swami SwarupanandaAdvaita Ashram (Publication Department), Kolkata.
2. Bhartrihari’s Three Satakam (Niti-sringar-vairagya) by P.Gopinath, Rashtriya Sanskrit Sansthanam, New Delhi

Web resource:

1. NTPEL:<http://nptel.ac.in/downloads/109104115/>

Course Code AC 004	CONSTITUTION OF INDIA (AUDIT COURSE-II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	2	-	-	3	40	60	0

Objectives:

- The history of Indian Constitution and its role in the Indian democracy.
- Address the growth of Indian opinion regarding modern Indian intellectuals' constitutional role and entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.
- Have knowledge of the various Organs of Governance and Local Administration.

Outcomes: Upon completing this course, students will be able to:

1. Understand the making of the Indian Constitution and its features.
2. Understand the Rights of equality, the Right of freedom and the Right to constitutional remedies.
3. Have an insight into various Organs of Governance - composition and functions.
4. Understand powers and functions of Municipalities, Panchayats and Co-operative Societies.
5. Understand Electoral Process, special provisions.

UNIT-I

History of making of the Indian constitutions: History, Drafting Committee(Composition & Working).**Philosophy of the Indian Constitution:** Preamble, Salient Features.

UNIT-II

Contours of Constitutional Rights and Duties Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

UNIT-III

Organs of Governance”: Parliament: Composition, Qualifications, Powers and Functions, Union executives : President, Governor, Council of Ministers, Judiciary, appointment and transfer of judges, qualifications, powers and functions.

UNIT-IV

Local Administration - District's Administration head: Role and importance. Municipalities: Introduction, ayor and role of Elected Representative, CEO of Municipal Corporation. Panchayati Raj: Introduction, PRI: Zilla Panchayat, Elected Officials and their roles, CEO Zilla Panchayat: positions and role. Block level: Organizational Hierarchy (Different departments) Village level: role of elected and appointed officials. Importance of grass root democracy.

UNIT-V

Election commission: Election Commission: Role and functioning, Chief Election Commissioner and Election Commissioners, State Election Commission :Role and functioning. Institute and Bodies for the welfare of SC/ST/OBC and women.

Suggested Reading:

1. The Constitution of India (Bare Act), 1950, Government of India, Ministry of Law and Justice, Latest Edition (2025).
2. Dr. S. N. Busi, *Dr. B. R. Ambedkar: Framing of Indian Constitution*, 1st Edition, 2015.
3. M. P. Jain, *Indian Constitutional Law*, 9th Edition, LexisNexis, 2023.
4. D. D. Basu, *Introduction to the Constitution of India*, 27th Edition, LexisNexis, 2024.

Web Resource:

1. <http://www.nptel.ac.in/courses/103107084/Script.pdf>

Course Code AC 005	PEDAGOGY STUDIES (AUDIT COURSE-II)						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	2	-	-	3	40	60	0

Course Objectives:

- Review existing evidence on the review topic to inform programme design and policy making undertaken by the DfID, other agencies and researchers.
- Identify critical evidence gaps to guide the development.

Course Outcomes:

1. What pedagogical practices are being used by teachers in formal and informal classrooms in Developing countries?
2. What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and with what population of learners?
3. How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?

UNIT-I

Introduction and Methodology:

- Aims and rationale, Policy background, Conceptual framework and terminology
- Theories of learning, Curriculum, Teacher education.
- Conceptual framework, Research questions.
- Overview of methodology and Searching.

UNIT-II

- Thematic overview: Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries.
- Curriculum, Teacher education.

UNIT-III

- Evidence on the effectiveness of pedagogical practices
- Methodology for the in depth stage: quality assessment of included studies.
- How can teacher education (curriculum and practicum) and the school
- Curriculum and guidance materials best support effective pedagogy?
- Theory of change.
- Strength and nature of the body of evidence for effective pedagogical practices.
- Pedagogic theory and pedagogical approaches.
- Teachers' attitudes and beliefs and Pedagogic strategies.

UNIT-IV

- Professional development: alignment with classroom practices and followup support
- Peer support
- Support from the head teacher and the community.
- Curriculum and assessment
- Barriers to learning: limited resources and large class sizes

UNIT-V

- Research gaps and future directions
- Research design
- Contexts
- Pedagogy
- Teacher education
- Curriculum and assessment
- Dissemination and research impact

Suggested reading:

1. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, *Compare*, 31 (2):245-261.
2. Agrawal M (2004) Curricular reform in schools: The importance of evaluation, *Journal of Curriculum Studies*, 36 (3): 361-379.
3. Akyeampong K (2003) Teacher training in Ghana - does it count? Multi-site teacher education research project (MUSTER) country report 1. London: DFID.
4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? *International Journal Educational Development*, 33 (3): 272–282.
5. Alexander RJ (2001) *Culture and pedagogy: International comparisons in primary education*. Oxford and Boston: Blackwell.
6. Chavan M (2003) Read India: A mass scale, rapid, 'learning to read' campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf.

Course Code ME 381	DISSERTATION PHASE I						Course Type Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	20	-	-		==	100	10

Course Objectives:

- Understand the purpose of Project work
- Learn the resources available at the college and outside for pursuing project
- Importance of literature review
- Learn to select appropriate software and procedure
- Learn to document results and arrive at required conclusions

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

1. Identify suitable engineering problems reviewing available literature.
2. Study different techniques used to analyze complex systems.
3. Use related techniques and software's for solving the problem
4. Interpret the results (if available) and defend work in front of technically qualified audience
5. Document the findings as a technical report with proper references

Guidelines

1. The Major Project Phase-I Work should preferably be a problem with research potential and should involve scientific research, design, generation/collection and analysis of data, determining solution and must preferably bring out the individual contribution.
2. Seminar should be based on the area in which the candidate has undertaken the dissertation work as per the common instructions for all branches of M.E.
3. The examination shall consist of the preparation of report consisting of a detailed problem statement and a literature review.
4. The preliminary results (if available) of the problem may also be discussed in the report.
5. The work has to be presented in front of the examiners panel set by Head and Faculty Advisor
6. The candidate has to be in regular contact with his guide and the topic of dissertation must be mutually decided by the guide and student.

Course Code ME 382	SEMISTER - IV DISSERTATION PHASE II						CourseType Core/PF/FE
Prerequisite if any	Contact hours per week			Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	P		CIE	SEE	
	32	-	-		--	200	

Course Objectives:

- Understand the purpose of doing project work
- Learn the resources available at the college and outside for pursuing project
- Importance of literature review
- Learn to select appropriate software and procedure
- Learn to document results and arrive at required conclusions

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

1. Use different Simulation models /experimental techniques/ software/ computational/analytical tools.
2. Design and develop Simulation model/Mathematical model/ experimental set up/ equipment/ testrig.
3. Conduct tests and draw logical conclusions from the results after analyzing them.
4. Work in either in research environment or in an industrial environment and Conversant with technical report writing.
5. Present and defend their work to the evaluation committee.

Guidelines

1. It is a continuation of Major Project Phase I work started in semester III.
2. The project work should be presented in standard format as provided by the department.
3. The candidate has to prepare a detailed project report consisting of introduction of the problem, problem statement, literature review, objectives of the work, methodology (experimental set up or numerical details as the case may be) adopted& Result analysis.
4. The report must bring out the conclusions of the work and future scope for the study and also should be properly referenced.
5. Student has to submit the report in prescribed format and also present a seminar.
6. Student should present a Seminar in front of Internal committee consisting of Head, CBoS, Guide, Subject expert, Faculty Advisor. Further the suggestions of the committee have to be incorporated in the final Report.
7. The final work has to be presented in front of the examiners panel consisting of an approved external examinerand a guide, co-guide etc. as decided by the Head and Faculty advisor.
8. The candidate has to be in regular contact with his guide.