# DEPARTMENT OF MECHANICAL ENGINEERING

## Curriculum and Syllabus for Minor Degree Programme

| | |
|---|---|
| **Name of the Minor Degree** | **ROBOTICS** |
| **Minor Degree Offering Department** | **MECH** |
| **Eligible Departments** | **All branches except MECH** |

| Sl. No. | Course Code | Course Title | L | T | P | Total Contact Periods | Credits |
|---|---|---|---|---|---|---|---|
| 1 | U23MDME01 | Introduction to Robotics | 3 | 0 | 0 | 3 | 3 |
| 2 | U23MDME02 | Basics in Mechanics | 3 | 0 | 0 | 3 | 3 |
| 3 | U23MDME03 | Kinematics of Robotics | 3 | 0 | 0 | 3 | 3 |
| 4 | U23MDME04 | Sensor and actuators in Robotics | 3 | 0 | 0 | 3 | 3 |
| 5 | U23MDME05 | PLC Programming of Robotics | 3 | 0 | 0 | 3 | 3 |
| 6 | U23MDME06 | Robotics path planning and programming | 3 | 0 | 0 | 3 | 3 |
| **TOTAL CREDITS** | | | | | | | **18** |

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| U23MDME01 | INTRODUCTION TO ROBOTICS | L | T | P | C |
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| | | 3 | 0 | 0 | 3 |

**Course Objectives:**

- To understand the operation and applications of stepper and servo motors
- To learn the fundamentals of digital electronics and Boolean logic
- To learn proficiency in analog electronics and Microprocessor fundamentals

**UNIT I** **INTRODUCTION TO ROBOTICS** 9

Brief History-Definition -Three laws -Robot anatomy-DOF- Misunderstood devices. Classification of Robotic systems- work volume- type of drive. Associated parameters- resolution, accuracy, repeatability, dexterity, compliance, RCC device. Introduction to Principles & Strategies of Automation-Types & Levels of Automations Need of automation- Industrial applications of robots

**UNIT II** **DIGITAL FUNDAMENTALS** 9

Stepper Motor: Classifications- Construction and Principle of Operation - Applications. Servo Mechanism – DC Servo motor - AC Servo motor. Number Systems – Decimal, Binary, Octal, Hexadecimal, 1's and 2's complements, Codes – Binary, BCD, Excess 3, Gray, Boolean theorems, Logic gates, Universal gates, Sum of products and product of sums

**UNIT III** **ANALOG ELECTRONICS** 9

Resistor, Inductor and Capacitor in Electronic Circuits- Semiconductor Materials: Silicon &Germanium – PN Junction Diodes, Zener Diode –Characteristics Applications – Bipolar Junction Transistor-Biasing, JFET, SCR, MOSFET,IGBT – Types, I-V Characteristics and Applications, Rectifier and Inverters

**UNIT IV** **PROGRAMMING PROCESSOR** 9

Instruction - format and addressing modes – Assembly language format – Data transfer, data manipulation & control instructions – Programming: Loop structure with counting & Indexing

**UNIT V** **MICROPROCESSOR & MICROCONTROLLER** 9

Introduction – Pin Configuration - Architecture of 8085 – Addressing Modes – Instruction set, Timing diagram of 8085-Microcontroller Systems -Single-Board Microcontroller Systems

**TOTAL: 45 PERIODS**

**TEXT BOOKS:**


1. Ganesh S Hedge, "A textbook of Industrial Robotics", 2nd Edition, Lakshmi Publications, 2006
2. Mikell P Groover "Industrial Robotics Technology, Programming and applications", 2nd Edition, Tata McGraw Hill, 2012


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**REFERENCES:**


1. Fu K S Gonalz R C, ice C S G "Robotics Control, Sensing, Vision and Intelligence", 2nd Edition, Tata McGraw Hill, 2007
2. Janakiraman P A, "Robotics and Image Processing", 3rd Edition, Tata McGraw Hill, 2005
3. Jazar, "Theory of Applied Robotics: Kinematics, Dynamics and Control", 3rd Edition, Springer, 2010


**ONLINE RESOURCES:**

1. https://nptel.ac.in/courses/112105249
2. https://archive.nptel.ac.in/courses/108/105/108105112/
3. https://nptel.ac.in/courses/108108076

**COURSE OUTCOMES:**

**Upon the completion of the course, the students will be able to**

**CO1** Explain the operation, types and applications of stepper and servo motors

**CO2** Apply digital electronics concepts to simplify logic circuits

**CO3** Analyze the characteristics and working principles of PN junction diodes and Zener diodes

**CO4** Write assembly language programs for debugging in microprocessors and interfacing

**CO5** Explain the principles and components of microprocessor and microcontroller

**CO-PO-PSO MAPPING:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PSO1 | PSO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO2 | 3 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO3 | 3 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO4 | 3 | 3 | 3 | 3 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO5 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |

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| U23MDME02 | BASICS IN MECHANICS | L | T | P | C |
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| | | 3 | 0 | 0 | 3 |

**Course Objectives:**

- To learn to use scalar and vector analytical techniques for analyzing forces in statically Determinate structures.
- To introduce the equilibrium of rigid bodies, vector methods and free body diagrams.
- To study and understand the distributed forces, surface, loading on beam and intensity.

**UNIT I** **STATICS OF PARTICLES** 9

Fundamental Concepts and Principles, Systems of Units, Method of Problem Solutions, Statics of Particles -Forces in a Plane, Resultant of Forces, Unit Vectors. Equilibrium of a Particle- Newton's First Law of Motion, Space and Free-Body Diagrams

**UNIT II** **EQUILIBRIUM OF RIGID BODIES** 9

Principle of Transmissibility, Equivalent Forces, Vector Product of Two Vectors, Moment of a Force about an Axis, Couple - Moment of a Couple, Equivalent Couples, Resolution of a Given Force into a Force -Couple system.

**UNIT III** **DISTRIBUTED FORCES** 9

Centroids of lines and areas – symmetrical and asymmetrical shapes, Determination of Centroids of Volumes by Integration. Moments of Inertia of Areas and Mass

**UNIT IV** **GEARS AND GEAR TRAINS** 9

Spur gear – law of toothed gearing – involute gearing – Interchangeable gears – Gear tooth action interference and undercutting – nonstandard teeth – gear trains – parallel axis gears trains – epicyclic gear trains

**UNIT V** **DYNAMICS OF PARTICLES** 9

Kinematics - Rectilinear Motion and Curvilinear Motion of Particles. Kinetics- Newton's Second Law of Motion -Equations of Motions, Dynamic Equilibrium, Energy and Principle of Work and Energy

**TOTAL : 45 PERIODS**

**TEXT BOOKS:**


1 Lynch, K M, Park, F C, "Modern Robotics: Mechanics, Planning and Control", 2nd Edition, Cambridge University Press, 2010

2 Ceccarelli, M," Fundamentals of Mechanics Manipulation of robotic", 2nd Edition, Springer International Publishing, 2013


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**REFERENCES:**


1 Boresi P, Schmidt J, "Engineering Mechanics: Statics and Dynamics", 2nd Edition, Cengage learning, 2008

2 Hibbeller, R C , "Engineering Mechanics: Statics and Engineering Mechanics" 2nd Edition, Pearson Education, 2007

3 Irving H Shames, Krishna Mohana Rao G, "Engineering Mechanics – Statics and Dynamics", 2nd Edition, Prentice Hall of India, 2005


**ONLINE RESOURCES:**

1 https://nptel.ac.in/courses/112/106/112106270/

2 https://ocw.mit.edu/courses/8-01sc-classical-mechanics-fall-2016/

3 https://www.khanacademy.org/science/mechanics

**COURSE OUTCOMES:**

**Upon the completion of the course, the students will be able to**

**CO1** Explain the vector and scalar representation of forces and moments

**CO2** Analyze the moment of a force about a point and an axis using vector algebra.

**CO3** Calculate the properties of distributed forces

**CO4** Design the gear teeth and gear train by the law of toothed gearing

**CO5** Calculate dynamic forces exerted in rigid body

**CO–PO–PSO MAPPING:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PSO1 | PSO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO2 | 3 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO3 | 3 | 2 | 1 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO4 | 3 | 3 | 3 | 3 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO5 | 3 | 2 | 1 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |

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| U23MDME03 | KINEMATICS OF ROBOTICS | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

**Course Objectives:**

- To introduce Robots history, terminologies, classification and configurations
- To get knowledge about basic Geometrical and Algebraic approach to solve forward kinematics of serial manipulator
- To get knowledge about advanced forward kinematics of serial manipulator

**UNIT I** **OVERVIEW OF ROBOTICS** 9

Introduction to Robotics - History - Definitions - Law of Robotics – Terminologies - Classifications Overview – Links & Joints - Degrees of Freedoms - Coordinate Systems - Work Volume - Precision, Repeatability & Accuracy - Position and Orientation of Objects - Roll, Pitch and Yaw Angles - Joint Configuration of Five Types of Serial Manipulators - Wrist Configuration- Overview of end effector

**UNIT II** **FORWARD KINEMATICS GEOMETRICAL AND ALGEBRAIC APPROACH** 9

Need for forward and Inverse Kinematics Equation – Parameters in Design and Control – Methods of forward and inverse kinematics- Geometric and Algebraic Approach in Forward Kinematics Solution, 1 DOF - 2 DOF Planar Robot (2P and 2R); 3DOF 2RP Spatial Robot

**UNIT III** **FORWARD KINEMATIC MODELING DENAVIT-HARTENBERG (DH) APPROACH** 9

Unit Circle Trigonometry - Translation Matrix - Rotation matrix, Euler Angles - Homogeneous Transformation - D-H and Modified D-H Convention and Procedures – Forward kinematics Solution using D-H Convention, Cartesian, Cylindrical, Spherical, SCARA and Articulated 3 DOF robots - 3 DOF robot with wrist

**UNIT IV** **INVERSE KINEMATICS MODELING** 9

Introduction to inverse kinematics -Issues in inverse kinematics - Inverse kinematics of 2 DOF Planar robot - 2 and 3 DOF planar and Spatial robot - Tool configuration - Inverse kinematics of 3 axis robot and 6 axis Robot - Inverse kinematics Computation- Closed loop solution

**UNIT V** **KINEMATIC MODELING OF DIFFERENTIAL DRIVE ROBOT** 9

Degree of Mobility, Steer ability and Maneuverability- Mobile Robot kinematics - Kinematic model and constraints, Mobile robot workspace – Representation of robot position – Kinematic models of differential wheel drive - Fixed wheel and steered wheel

**TOTAL : 45 PERIODS**

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**TEXT BOOKS:**

1 Mikell P Groover, "Industrial Robotics", 2nd Edition, Tata McGraw Hill, 2012

2 Lynch, Kevin M, and Frank C, "Park Modern Robotics: Mechanics, Planning and Control", 1st Edition, Cambridge University Press, 2017

**REFERENCES:**

1 S K Saha , "Introduction to Robotics", 2nd Edition, Tata McGraw-Hill, 2017

2 John J Craig, "Introduction to Robotics", 3rd Edition, Pearson Education , 2021

3 Arthor Critchlow, "Introduction to Robotics", 1st Edition, Macmillan , 2009

**ONLINE RESOURCES:**

1 https://archive.nptel.ac.in/courses/112/105/112105236/
2 https://onlinecourses.nptel.ac.in/noc21_me76/preview
3 https://archive.nptel.ac.in/courses/112/105/112105249/

**COURSE OUTCOMES:**

**Upon the completion of the course, the students will be able to**

**CO1** Explain the basic terminologies of robotics and its classification

**CO2** Evaluate forward kinematic model for planar and spatial robot manipulator

**CO3** Evaluate the transformation matrices including translation and rotation matrices, to model position of robotic links

**CO4** Explain the concept of inverse kinematics and its significance in robotic motion planning and control.

**CO5** Analyze the kinematic model for differential drive mobile robot

**CO-PO-PSO MAPPING:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PSO1 | PSO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO2 | 3 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO3 | 3 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO4 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO5 | 3 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |

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| U23MDME04 | SENSORS AND ACTUATORS | L | T | P | C |
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**Course Objectives:**

- To understand the concepts of measurement technology.
- To learn the fundamentals of signal conditioning, data acquisition and communication systems used in mechatronics system development.
- To understand the signal conditioning and DAQ systems.

**UNIT I** **INTRODUCTION** 9

Basics of Measurement – Classification of errors – Error analysis – Static and dynamic characteristics of transducers – Performance measures of sensors – Classification of sensors – Sensor calibration techniques – Sensor Output Signal Types

**UNIT II** **MOTION, PROXIMITY AND RANGING SENSORS** 9

Motion Sensors – Potentiometers, Resolver, Encoders – Optical, Magnetic, Inductive, Capacitive, LVDT – RVDT – Synchro – Microsyn, Accelerometer – GPS, Bluetooth, Range Sensors – RF beacons, Ultrasonic Ranging, Reflective beacons, Laser Range Sensor (LIDAR).

**UNIT III** **FORCE, MAGNETIC AND HEADING SENSORS** 9

Strain Gage, Load Cell, and Magnetic Sensors –types, principle, requirement and advantages: Magneto resistive – Hall Effect – Current sensor Heading Sensors – Compass, Gyroscope, Inclinometers

**UNIT IV** **OPTICAL, PRESSURE AND TEMPERATURE SENSORS** 9

Force, torque, power — mechanical, Pneumatic, Hydraulic and Electrical type. bimetallic strip, thermocouples, electrical resistance thermometer — Reliability and Calibration

**UNIT V** **SIGNAL CONDITIONING AND DAQ SYSTEMS** 9

Amplification – Filtering – Sample and Hold circuits – Data Acquisition: Single channel and multi-channel data acquisition – Data logging - Applications - Automobile, Aerospace, Home appliances, Manufacturing and Environmental monitoring

**TOTAL: 45 PERIODS**

**TEXT BOOKS:**


1. Ernest O Doebelin , "Measurement Systems – Applications and Design", 2nd Edition ,Tata McGraw Hill, 2009
2. Sawney A K, Puneet Sawney , "A Course in Mechanical Measurements and Instrumentation and Control", 12th Edition, Dhanpat Rai , 2013


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**REFERENCES:**


1 Richard Zurawski, "Industrial Communication Technology Handbook", 2nd Edition, CRC Publications, 2015

2 Patranabis D, "Sensors and Transducers", 2nd Edition Prentice Hall of India publication, 2011

3 Hans Kurt Tonshoff, Ichiro, "Sensors in Manufacturing", 2nd Edition, John Wiley & sons, 2021


**ONLINE RESOURCES:**

1 https://onlinecourses.nptel.ac.in/noc21_ee32/preview

2 http://ndl.iitkgp.ac.in/he_document/nptel/16331_16332

3 http://digimat.in/nptel/courses/video/108108147/L01.html

**COURSE OUTCOMES:**

**Upon the completion of the course, the students will be able to**

**CO1** Explain the various calibration techniques and types of sensors

**CO2** Describe the working principle and characteristics of force, magnetic, heading, pressure and temperature sensors

**CO3** Explain the sensors and transducers in various applications

**CO4** Analyze the reliability and calibration aspects in measurement systems

**CO5** Describe the operation and importance of data logging in various applications

**CO-PO-PSO MAPPING:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PSO1 | PSO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO2 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO3 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO4 | 3 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO5 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |

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| U23MDME05 | PLC PROGRAMMING OF ROBOTICS | L | T | P | C |
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**Course Objectives:**

- Understand basic PLC terminologies, digital principles, PLC architecture and operation
- Familiarize different programming language of PLC
- Develop PLC logic for simple applications using ladder logic

**UNIT I** **INTRODUCTION TO PLC** 9

Introduction to PLC: Microprocessor, I/O Ports, Isolation, Filters, Drivers, Microcontrollers/DSP, PLC/DDC- PLC Construction: PLC, PLC Memories, PLC I/O,PLC Special I/O, PLC Types

**UNIT II** **PLC INSTRUCTIONS** 9

PLC Basic Instructions: PLC Ladder Language- Function block Programming-Ladder/Function Block functions- PLC Basic Instructions, Basic Examples (Start Stop Rung, Entry/Reset Rung)- Configuration of Sensors, Switches, Solid State Relays-Interlock examples- Timers, Counters, Examples

**UNIT III** **PLC PROGRAMMING** 9

Different types of PLC program, Basic Ladder logic, logic functions, PLC module addressing, registers basics, basic relay instructions, Latching Relays, data handling, data move functions, timer-counter instructions, input-output instructions, sequencer instructions

**UNIT IV** **COMMUNICATION OF PLC AND SCADA** 9

Communication Protocol – Modbus, HART, Profibus, SCADA: Hardware and software, Remote terminal units, Master Station and Communication architectures

**UNIT V** **CASE STUDIES** 9

Stepper Motor Control - Elevator Control-CNC Machine Control- conveyor control-Interlocking Problems

**TOTAL: 45 PERIODS**

**TEXT BOOKS:**


1. Frank Petruzzula,"Programmable Logic Controllers",2nd Edition, Tata McGraw Hill , 2008
2. John W Webb, Ronald A Reis, "Programmable Logic Controllers Principles and Applications", 2nd Edition, Prentice Hall of India, 2019


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**REFERENCES:**


1. Madhuchhanda Mitra, Samarjit Sengupta, "Programmable Logic Controllers Industrial Automation and Introduction", 3rd Edition, Penram publishing, 2020
2. J R ackworth, F D Hackworth, "Programmable Logic Controllers Principles and Applications", 2nd Edition, Pearson Education , 2017
3. Hans Kurt Tonshoff, Ichiro, "Sensors in Manufacturing", 3rd Edition, John Wiley & Sons, 2001


**ONLINE RESOURCES:**

1. https://nptel.ac.in/courses/108/105/108105062
2. https://nptel.ac.in/courses/112/107/112107297
3. https://archive.nptel.ac.in/courses/112/102/112102011/

**COURSE OUTCOMES:**

**Upon the completion of the course, the students will be able to**

**CO1** Explain the basic requirement of a PLC input/output devices and architecture

**CO2** Apply the Basics Instruction Sets used for ladder Logic and Function Block Programming

**CO3** Apply data handling and data move functions effectively in PLC-based systems

**CO4** Analyze the communication architecture between SCADA components in a control system.

**CO5** Explain the Concepts of Communication used for PLC/SCADA

**CO-PO-PSO MAPPING:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PSO1 | PSO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO2 | 3 | 2 | 1 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO3 | 3 | 2 | 1 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO4 | 3 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO5 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |

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| U23MDME06 | ROBOT PATH PLANNING AND PROGRAMMING | L | T | P | C |
|---|---|---|---|---|---|
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**Course Objectives:**

- To introduce the fundamental concepts of robot motion and path planning
- To understand the principles and techniques of robot programming
- To understand path planning programming strategies and expose students to real-time applications

**UNIT I** **TRAJECTORY PLANNING APPROACHES** 9

Definitions – Task planning and Trajectory planning – Representation of end-effector: Cartesian and joint space schemes -Workspace Analysis: work envelope of a multi DOF manipulator - Applications: Point to point motion and continuous path motion

**UNIT II** **TRAJECTORY PLANNING OF MANIPULATOR** 9

Joint space techniques – Motion profiles – Cubic polynomial, Linear Segmented Parabolic Blends and cycloidal motion – Straight line and circular trajectories

**UNIT III** **PATH PLANNING OF MOBILE ROBOT** 9

Introduction - Representation of the Robot's Environment - Review of configuration spaces - Visibility Graphs - Voronoi diagrams – Attractive and Repulsive– Planning with moving obstacles - Probabilistic Roadmaps - Random trees

**UNIT IV** **PATH PLANNING ALGORITHMS** 9

Planning - A* Algorithm - the D*Algorithm - Path control-Graph search and discrete planning algorithms - Sensor-Based Motion Planning Algorithms

**UNIT V** **ROS PROGRAMMING** 9

Introduction to Robot Operating System (ROS) - ROS examples - Introduction to programming using ROS - Industrial ROS - Programming for point to point /continuous – operations - Case Study

**TOTAL: 45 PERIODS**

**TEXT BOOKS:**


1. Mason, M T , " Mechanics of Robotic Manipulation", 2nd Edition, MIT Press , 2016
2. LaValle, S M, "Planning algorithms Italy: Cambridge University", 3rd Edition, Cambridge University Press, 2008


**REFERENCES:**


1. Rafael C Gonzales, Richard E Woods, "Digital Image Processing ", 4th Edition, Pearson Education, 2015
2. Emanuele Trucco, Alessandro Verri, "Introductory Techniques for 3D Computer Vision", 1st Edition, Prentice Hall of India , 2008
3. Hans Kurt Tonshoff, Ichiro, "Sensors in Manufacturing", 3rd Edition, John Wiley & Sons publications, 2016


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**ONLINE RESOURCES:**

1 https://archive.nptel.ac.in/courses/112/104/112104308/
2 https://nptel.ac.in/courses/112105249
3 https://ocw.mit.edu/courses/2-12-introduction-to-robotics-fall-2005/

**COURSE OUTCOMES:**

**Upon the completion of the course, the students will be able to**

CO1 Apply trajectory planning techniques for both point-to-point and continuous path motion in robotic applications

CO2 Describe the trajectory planning and path planning for mobile robot and Manipulator

CO3 Apply the Path and Trajectory planning algorithms for various Applications

CO4 Analyze heuristic-based algorithms such as A* and D* for optimal path finding

CO5 Design a path and trajectory for real time robot applications

**CO–PO–PSO MAPPING:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PSO1 | PSO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO2 | 2 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO3 | 3 | 2 | 1 | 1 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO4 | 3 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |
| CO5 | 3 | 3 | 3 | 3 | - | 1 | - | - | - | - | - | 1 | 2 | 1 |

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