Walchand College of Engineering, Sangli

(Government Aided Autonomous Institute)

AY 2026-27

Course Information	
Programme	B.Tech. (Robotics & Automation Engineering)
Class, Semester	Third Year B. Tech., Sem V
Course Code	1RA301
Course Name	Control Systems in Robotics
Desired Requisites:	Engineering Mathematics III, Fundamentals of Electrical Engineering

Teaching Scheme		Examination Scheme (Marks)			
Lecture	2 Hrs/week	**MSE**	**ISE**	**ESE**	**Total**
Tutorial	1 Hr/week	30	20	50	100
		Credits: 3			

Course Objectives	
1	To introduce the fundamental concepts of feedback control systems and their significance in robotics and automation applications.
2	To impart knowledge of mathematical modeling techniques for robotic actuators, servo systems, and mechatronic systems using transfer function and state-space representations.
3	To enable students to analyze the dynamic performance and stability of robotic control systems using time-domain and frequency-domain methods.
4	To familiarize students with PID controllers, compensators, and their application in motion control and trajectory tracking of robotic systems.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	**Develop** mathematical models of robotic and mechatronic systems using transfer functions and state variables.	III	Applying
CO2	**Analyze** dynamic performance of robotic control systems using time-domain specifications.	IV	Analyzing
CO3	**Evaluate** stability and performance of feedback control systems used in robotics and automation.	V	Evaluating
CO4	**Select** and **implement** suitable controllers for motion and position control applications in robotic systems.	V	Evaluating

Module	**Module Contents**	**Hours**
I	**Modeling of Robotic and Mechatronic Systems** Introduction to control systems in robotics and automation, Open-loop and closed-loop control systems, Mathematical modeling concepts, Transfer function representation Modeling of: DC Servo Motor, Robotic joint actuator Position and speed control systems, Applications in industrial robots and autonomous systems	4

II	**Dynamic Response of Control Systems** Time-domain specifications: Rise time, Settling time, Peak overshoot, Steady-state error, First-order and second-order systems, Effect of damping ratio on robotic motion, Response characteristics of servo positioning systems, Introduction to performance requirements in robotic applications	5
III	**Control System Representation and Analysis** Block diagrams and simplification rules, Signal flow graphs and Mason's Gain Formula, Concept of feedback in robotic systems, Disturbance rejection and noise attenuation, Case studies: Mobile robot speed control, Robotic arm position control, Conveyor automation systems	5
IV	**Stability and Controller Design** Concept of stability and its significance in robotics, Relative stability, Introduction to poles and zeros, Qualitative understanding of Root Locus, Introduction to PID control, Tuning effects of P, PI and PID controllers, Industrial examples of PID-controlled robotic systems	4
V	**State Space Concepts for Robotic Systems** Need for state-space representation, State variables and state equations, State-space modeling of simple robotic systems, Conversion between transfer function and state-space form, Concepts of controllability and observability (qualitative treatment), Applications in modern robotic controllers	5
VI	**Frequency Response and Practical Control Applications** Introduction to frequency response, Bode plots, Gain margin and phase margin concepts, Lead and lag compensators, Control architecture in robotic systems: Servo control, Motion control. Trajectory tracking, Industrial automation applications, Case studies using robotic and automation systems	5

Textbooks	
1	Norman Nise, "Control System Engineering", John Wiley, Seventh Edition, 2014.
2	K Ogata, "Modern Control Engineering", P.H.I., Fourth Edition, 2002.

References	
1	M Gopal, "Control System Principle & Design", T.M.H., Fourth Edition, 2012.
2	K Ogata, "Modern Control Engineering", P.H.I., Fourth Edition, 2002.
3	Dorf and Bishop, "Modern Control System", Adison Wesley Longman, Eight Edition, 1998.
4	I.J. Nagrath and M. Gopal, "Control System Engineering", Anshan Publishers, Fifth edition, 2008.

Useful Links	
1	https://nptel.ac.in/courses/108106098
2	https://nptel.ac.in/courses/108102044

CO-PO Mapping														
	Programme Outcomes (PO)												**PSO**	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3	2											3	2
CO2	3	3		2									3	2
CO3	3	3	2	2									3	3
CO4	3	2	3	2	2								3	3

Assessment
The assessment is based on MSE, ISE and ESE. MSE shall be typically on modules 1 to 3. ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO. ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6. For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (ESE shall be a separate head of passing)

Walchand College of Engineering, Sangli

(Government Aided Autonomous Institute)

AY 2025-26

Course Information	
Programme	B.Tech. (Robotics & Automation Engineering)
Class, Semester	TY B. Tech., Sem V
Course Code	1RA302
Course Name	Mechanisms for Robotics and Automation
Desired Requisites:	Engineering Mechanics, Engineering Mathematics, Engineering Drawing.

Teaching Scheme		Examination Scheme (Marks)			
Lecture	3 Hrs/week	**MSE**	**ISE**	**ESE**	**Total**
Tutorial	-	30	20	50	100
		Credits: 3			

Course Objectives	
1	To build a strong understanding of links, joints, kinematic chains, mobility, and inversions of mechanisms used in robots and automation.
2	To enable students to analyze and synthesize planar and basic spatial mechanisms for motion generation and task-oriented movement.
3	To develop knowledge of cams, intermittent motion mechanisms, gear trains, and precision transmission systems used in automation.
4	To expose students to robotic wrist mechanisms, compliance, and special-purpose mechanisms that support industrial automation.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	Analyze links, kinematic pairs, mobility, and inversions of mechanisms used in robotic and automation systems.	IV	Analyze
CO2	Analyze position, velocity, and acceleration of linkage mechanisms and synthesize simple linkage-based motion tasks.	V	Analyze
CO3	Evaluate cam, Geneva, and other intermittent motion mechanisms for automated sequencing and indexing.	VI	Evaluate
CO4	Design and select suitable transmission, compliance, and special robotic mechanisms for given robotics and automation applications.	VI	Create

Module	**Module Contents**	**Hours**
I	**Fundamentals of Mechanisms and Mobility** Mechanisms vs. machines; links and link classification; kinematic pairs; constrained motion; lower and higher pairs; kinematic chains. Planar and spatial mechanisms; mobility and degree of freedom calculation using the Gruebler-Kutzbach criterion. Kinematic inversions of four-bar and slider-crank mechanisms, with a focus on their applications in robotic joints, manipulators, and basic automation equipment.	6

II	**Kinematic Analysis and Synthesis of Linkages** Position analysis of mechanisms; relative velocity analysis; relative acceleration analysis; instantaneous center method; Aronhold-Kennedy theorem; graphical and introduction to analytical methods; path generation; function generation; motion generation;	6
III	**Cam and Intermittent Motion Mechanisms** Classification of cams and followers. Conceptual overview of follower motion laws (SHM, cycloidal), pressure angles, and undercutting. Geneva mechanism; ratchet and pawl mechanism; indexing devices; intermittent motion mechanisms; applications in packaging, sorting, assembly and automated production systems.	6
IV	**Gear Trains and Motion Transmission in Robotics** Fundamental law of gearing; gear terminology; involute tooth profile; spur, helical, bevel and worm gears; velocity ratio; simple gear trains; compound gear trains; reverted gear trains; epicyclic gear trains; differential gear arrangements; transmission of motion and torque; speed reduction and multiplication; backlash; applications in robotic joints and automation machinery.	7
V	**Traditional Gyroscopes, Balancing and MEMS Inertial Sensors** Construction and working of gyroscopes; spin, precession; gyroscopic couple and gyroscopic effects; applications in ships, aircraft, and stabilization systems; gyroscopic effects in mobile robots, UAVs and robotic platforms. Introduction to MEMS technology and understanding the Coriolis principle as applied to sensors. How Inertial Measurement Units (IMUs) function to track orientation and balance in robotic platforms. Conceptual overview of vibration reduction in high-speed mechanisms.	6
VI	**Special Robotic Mechanisms and Automation Systems** Robot wrist mechanisms; differential mechanisms; serial and parallel mechanisms; compact motion-transmission arrangements for robotic wrists; cable and tendon-driven mechanisms; passive compliance; remote center compliance (RCC); compliant mechanisms; mechanisms for robotic assembly systems; pick-and-place automation; packaging automation; industrial robot case studies and automation system case studies.	9

Textbooks	
1	**Rattan, S. S.** *Theory of Machines*. McGraw-Hill Professional Publishing, 1993.
2	**Ghosh, A., & Mallik, A. K.** ***Theory of Mechanisms and Machines*****, 3rd ed. East West Press Pvt. Ltd., 2009.**
3	**Saha, S. K.** *Introduction to Robotics*. Tata McGraw-Hill, 2014.
References	
1	**Waldron, K. J., Kinzel, G. L., & Agrawal, S. K.** *Kinematics, Dynamics and Design of Machinery*, 3rd ed. Wiley Student Edition, 2016.
2	**Uicker, J. J., Pennock, G. R., & Shigley, J. E.** *Theory of Machines and Mechanisms*, 3rd ed. Oxford International Student Edition, 2003
3	**Mallik, A. K., Ghosh, A., & Dittrich, G.** *Kinematic Analysis and Synthesis of Mechanisms*. CRC Press, 1994.
4	**Rao, J. S., & Dukkipati, R. V.** *Mechanism and Machine Theory*. New Age International, 2006.
Useful Links	
1	https://onlinecourses.nptel.ac.in/e-learning/preview/noc20_me21
2	https://onlinecourses.nptel.ac.in/e-learning/preview/noc20_me53
3	https://onlinecourses.nptel.ac.in/e-learning/preview/noc22_me50
4	https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_me01
CO-PO Mapping	

	Programme Outcomes (PO)												PSO	
	1	2	3	4	5	6	7	8	9	10	11		1	2
CO1	3	2	-	-	-	-	-	-	-	-	-	2	-	3
CO2	3	3	2	-	-	-	-	-	-	-	-	3	-	3
CO3	3	2	2	-	-	-	-	-	-	-	-	2	2	3
CO4	3	2	3	-	-	-	-	-	-	-	1	3	2	3

Assessment
The assessment is based on MSE, ISE and ESE. MSE shall be typically on modules 1 to 3. ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO. ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6. For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (ESE shall be a separate head of passing)

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AY 2026-27

Course Information

Programme	B. Tech. (Robotics & Automation)
Class, Semester	Third Year B. Tech., Sem. V
Course Code	1RA303
Course Name	Embedded Systems
Desired Requisites:	8051 Microcontroller, Digital Electronics, C, C++ programming

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	2 Hrs/week	**MSE**	**ISE**	**ESE**	**Total**
Tutorial	-	30	20	50	100
	-	**Credits: 2**			

Course Objectives

1	To state the difference between ARM and 8051 Microcontroller.
2	To explain the Architecture, Organization and Instruction set of ARM.
3	To implement Assembly, C and C++ programming language for embedded system.
4	To study the Real Time Operating System (RTOS) in comparison with other Operating System.
5	To recommend student to provide solution for real word problem using embedded system.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	**Describe** the Architecture and Special built in blocks of ARM.	II	Understand
CO2	**Apply** Assembly, C and C++programming for embedded system.	III	apply
CO3	**Explain** the Interfacing of external peripherals devices with ARM.	IV	Analysing
CO4	**Discuss** the Real Time Operating System (RTOS) for embedded system	V	Evaluating

Module	**Module Contents**	**Hours**
I	**Acorn RISC Machine Architecture** Complex Instruction Set Computer(CSIC), Reduced Instruction Set Computer (RISC), ARM7 /ARM Cortex M3 Architecture, Microcontroller pin layout ,Memory organization, Register Structure, Current Program Status Register(CPSR), System bus and peripherals, Memory Accelerator module, ARM Development Tools, Compare features/ architecture of ARM with 8051.	5
II	**ARM Organization and Instruction Set** ARM Pipeline Organization, ARM Assembly Language Programming – Data Processing Instructions, Data Transfer Instruction, Control Flow Instruction, ARM Instruction Execution – Conditional Execution, Exceptions, Branch with link and exchange, , PLL configuration, Pin Connect Block.	4
III	**Devices and Communication Buses** I/O types and I/O Programming, Serial Communication Devices, Parallel Device Ports, Wireless Devices, Block diagram of Timers, role of prescaler, Capture and Match facility of timer and configuration of it using registers, Pulse Width Modulator, RTC operation and Programming, Watch dog timer, Network protocols.	5
IV	**Communication Protocols and Interrupt Structure** On chip serial ports, Serial port programming, setting baud rate, Using UART buffer, printf for serial data transfer, interrupt based serial port handling I2C protocol, Using I2C for interfacing external EEPROM, SPI protocol and programming. Interrupt system in ARM7/ ARM Cortex M3, Interrupt Controller, FIQ, IRQ, Non-vectored interrupt, Software interrupt, Interrupt latency, Nested interrupts, External interrupts, Interrupt configuration and Programming examples.	6
V	**ARM Peripherals Interfacing using C, C++ Programming** C Program Elements, Macros and Functions, Data types, Data Structure, Modifier, Loop and Pointers, Object-Oriented Programming, Embedded Programming in C++, External Peripheral Interfaces like LED, switch, LCD , Keypad and touchscreen , Motor Seven Segment Display, DC motor and Stepper motor, etc.	4
VI	**Basics of Real Time Operating System** Real Time Operating System(RTOS) based embedded system Design, Operating System basic, Types of operating systems, Tasks, Process and Threads, Multi processing and	3

	Multitasking, Task scheduling.	

Text Books	
1	Kamal, Raj, Embedded Systems : Architecture, Programming and Design - 2nd Ed. - Tata McGraw-Hill Publishing Company Limited 2008
2	Sloss, Andrew N. & Symes, Dominic, ARM System Developers Guide Designing and Optimizing System Software - 1st Ed. - Morgan Kaufman Publication 2005
3	Furber, Steve, ARM System-On-Chip Architecture - 1st Ed. - UP Pearson India Education Services Pvt. Ltd. 2016
4	Joseph Yiu, "The Definitive Guide to ARM® Cortex®- M3 and Cortex® -M4 Processors", 3rd Edition, UK Newnes 2014
5	Kris Schindler "Introduction to Microprocessor Based System Using the ARM Processor"

References	
1	Zurawski, R. Embedded Systems Handbook Networked Embedded Systems - 2nd Ed. - CRC Press 2009
2	Yifeng Zhu , "Embedded Systems with Arm Cortex - M Microcontroller Assembly Language and CT", E-Man Press LL
3	Frank Vahid and Tony Givargis, "Embedded System Design" Wiley publication
4	Embedded Microcomputer Systems - Real Time Interfacing - Jonathan W. Valavano, Cengage, Learning; Third edition.

Useful Links	
1	*www.mkp.com/companions/1558608745*
2	*www.cs.man.ac.uk/amulet/publications/books/ARMsysArch* /
3	*www.mhhe.com/kamal/emb2*
4	www.rajkamal.org /

CO-PO Mapping

	Programme Outcomes (PO)												PSO	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3													
CO2	3													
CO3		3			3									
CO4			3				1							2

The strength of mapping is to be written as 1: Low, 2: Medium, 3: High
Each CO of the course must map to at least one PO.

Assessment

The assessment is based on MSE, ISE and ESE.
MSE shall be typically on modules 1 to 3.
ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO.
ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6.
For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (ESE shall be a separate head of passing)

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AY 2026-27

Course Information

Programme	B.Tech. (Robotics & Automation)
Class, Semester	Third Year B. Tech., Sem. V
Course Code	1RA304
Course Name	Digital Signal Processing
Desired Requisites:	Basics of analog and digital communication

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	3 Hrs/week	**MSE**	**ISE**	**ESE**	**Total**
Tutorial	-	30	20	50	100
	-	**Credits: 3**			

Course Objectives

1	To understand basic signals and mathematical operations on signals
2	To understand the Discrete Fourier transform and Fast Fourier Transform.
3	To summarize the Digital Filter Structure for FIR and IIR filter.
4	To apply different windowing techniques in time domain and frequency domain.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	Course Outcome Statement/s	Bloom's Taxonomy Level	Bloom's Taxonomy Description
CO1	Describe signals mathematically and understand their classification.	I	Remember
CO2	Analyse the Discrete Fourier Transform and the Fast Fourier Transform Algorithms.	II	Analyse
CO3	Design the FIR, IIR Digital Filters with given specifications.	IV	Create
CO4	Describe the fundamentals of Multi rate DSP.	IV	Remember

Module	Module Contents	Hours
I	**Introduction to DSP** Signals, Systems, Signal Processing, Classification of Signals, Classification of Systems, Concept of Time Domain and Frequency domain, Concept of frequency in continuous time and discrete time signals, Convolution, Auto-Correlation, Cross correlation.	7
II	**Discrete Fourier Transform** Frequency Analysis of Continuous-Time Signals: Fourier Series and Fourier Transform, Frequency Analysis of Discrete-Time Signals: The Discrete Time Fourier Series (DTFS), The Discrete-Time Fourier Transform (DTFT) and the Discrete Fourier Transform (DFT), Inverse IDFT, Parseval's Theorem, Properties of DFT.	6
III	**Fast Fourier Transform** Fast Fourier Transform (FFT) algorithms – Radix-2 and Radix-4 FFT algorithms, Decimation in Time, Decimation in Frequency algorithms, Inverse Fast Fourier Transform, Use of FFT algorithms in Linear Filtering and correlation.	5
IV	**Realization of Digital Filters** Types of filters, Block diagram representation, Equivalent Structure, Realization of FIR Filter, Realization of IIR Digital Filter.	7

V	**Filter Design Techniques-FIR Filters** Introduction, Design of FIR Filter by Windowing, Properties of commonly used windows, Linear Phase property of FIR Filter, Kaiser Window Filter design, Design of Discrete-time IIR Filters from Continuous-time Filters, Filter Design by Impulse Invariance, Filter Design by Bilinear Transformation, Frequency Transformations of Low pass IIR Filters.	7
VI	**Multirate Digital Signal Processing** Decimation by Factor *D*, Interpolation by Factor *I*. Sampling rate conversion by rational factor *I/D*. Implementation of sampling rate conversion Multistage Implementation of Sampling Rate Conversion, Sampling rate conversion by arbitrary factor. Applications of Multirate Signal Processing.	7

Text Books	
1	Mitra, S.K. Digital Signal Processing A Computer Based Approach - 4th Ed. - New Delhi Mc Graw Hill Education (India) Pvt.Ltd. 2014.
2	Proakis J.G. & Manolakis D.G. Digital Signal Processing Principles Algorithms... - 4th Ed. - Delhi Pearson Prentice Hall 2014
3	Chassaing, R. & Reay, D. Digital Signal Processing Applications with the Tms 320C6713 and 320C6416DSKTms - 2nd Ed. - New Delhi Wiley India Pvt. Ltd. 2014
4	Kumar, A. Anand Digital Signal Processing - 2nd Ed. - Delhi PHI Learning Private Limited 2015

References	
1	W. D. Stanley, G. R. Dougherty, and R. Dougherty, “Digital Signal Processing” Reston Publication Reston, VA 1984
2	Babu, P. Ramesh Digital Signal Processing : A Practical Guide for Engineers and Scientists - 1st Ed. - Scitech Publications
3	Madisetti, V & K. The Digital Signal Processing Handbook : Digital Signal Processing Fundamentals - 2nd Ed. - New York CRC Press 2010

Useful Links	
1	*www.mhhe.com/mitra*
2	*www.d-filter.ece.uvic.ca*
3	*www.ece.uvic.ca/~andreas*
4	*www.mhhe.com/salivahanan/dsp3e*

CO-PO Mapping

	Programme Outcomes (PO)												**PSO**	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3													
CO2	3													
CO3		3			3									
CO4			3				1							

The strength of mapping is to be written as 1: Low, 2: Medium, 3: High
Each CO of the course must map to at least one PO.

Assessment

The assessment is based on MSE, ISE and ESE. MSE shall be typically on modules 1 to 3.
ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO.
ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6.
For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (ESE shall be a separate head of passing)

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AY 2026-27

Course Information

Programme	B. Tech. Robotics and Automation
Class, Semester	Third Year B. Tech., Sem. V
Course Code	1RA351
Course Name	Automation Lab
Desired Requisites:	Elements of Robotics and Automation, Engineering Graphics, Computer Programming

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	-	**LA1**	**LA2**	**Lab ESE**	**Total**
Tutorial	-	30	30	40	100
Practical	2 hrs/week				
Interaction	-	**Credits: 1**			

Course Objectives

1	To familiarize students with the fundamentals of robotic simulation, offline programming, and virtual manufacturing environments using RoboDK and Visual Components.
2	To develop skills in robot modelling, path planning, task programming, and simulation of industrial robotic operations.
3	To enable students to design, simulate, and validate automated manufacturing systems, material handling systems, and production layouts in a virtual environment.
4	To provide hands-on experience in analysing, optimizing, and integrating robotic and automation solutions for industrial applications using digital manufacturing tools.

Course Outcomes (CO)

CO	Description	Blooms Taxonomy	
		Level	Descriptor
CO1	Explain coordinate transformations, offline programming logic, and the structural integration of material handling subsystems within simulated automated cells.	II	Explain
CO2	Construct operational kinematic profiles, cycle-time validations, and optimized trajectories for industrial applications (Welding/Palletizing) within digital environments.	III	Construct
CO3	Analyze material flow rates, queueing behaviors, and operational bottlenecks across layout networks utilizing conveyors, buffers, and workstations.	IV	Analyze
CO4	Evaluate multi-resource digital factory layout designs against key throughput KPIs, equipment efficiencies (OEE), and resource starvation or blocking constraints.	V	Evaluate

List of Experiments / Lab Activities

List of Experiments:

PART A :

1. Introduction to RoboDK Interface, Coordinate Systems, Robot Selection, and Basic Robot Manipulation
2. Creation of Pick-and-Place Simulation Using Industrial Robot and Gripper
3. Offline Programming and Path Generation for Material Handling Operations
4. Simulation and Validation of Robotic Welding/Palletizing Work cell with Cycle Time Analysis

Note: Recommended use of RoboDK software for PART A, as it is available.

PART B

1. Introduction to Visual Components Interface, Library Components, and Layout Creation
2. Development of Basic Manufacturing Cell Using Conveyors, Buffers, and Workstations
3. Simulation and Analysis of Material Flow in an Automated Production Line
4. Design and Validation of a Digital Factory Model Incorporating Robot, Conveyor, and Production Resources

Note: Recommended use of Visual Components software for PART B, as it is available.

Text Books	
1	Industrial Robotics: Technology, Programming and Applications, Mikell P. Groover, Tata McGraw-Hill
2	Automation, Production Systems, and Computer-Integrated Manufacturing, Mikell P. Groover, Pearson Education
References	
1	Manufacturing Automation: Metal Cutting Mechanics, Machine Tool Vibrations and CNC Design, Yoram Koren, CRC Press
2	Simulation Modeling and Analysis, Averill M. Law, McGraw-Hill
Useful Links	
1	https://robodk.com/doc/en/Main-Documentation.html
2	https://robodk.com/academy
3	https://academy.visualcomponents.com
4	https://help.visualcomponents.com

CO-PO Mapping

	Programme Outcomes (PO)											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	-	3	-	-	-	2	1	-		
CO2	3	3	2	2	3	-	-	-	2	2	-		
CO3	3	3	3	3	3	1	1	-	2	1	2		
CO4	3	3	3	3	3	1	2	-	3	2	3		

The strength of mapping: 1:Low, 2:Medium, 3:High

Assessment

There are three components of lab assessment, LA1, LA2, and Lab ESE
IMP: Lab ESE is a separate head of passing. Lab ESE is treated as End Semester Exam and is based on all experiments/lab activities.

Assessment	Based on	Conducted by	Typical Schedule	Marks
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 6 Marks Submission at the end of Week 6	30
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 7 to Week 12 Marks Submission at the end of Week 12	30
Lab ESE	Lab Performance and documentation	Lab Course faculty	During Week 13 to Week 18 Marks Submission at the end of Week 18	40

Week 1 indicates the starting week of a semester. The actual schedule shall be as per the academic calendar. Lab activities/Lab performance shall include performing experiments, mini-projects, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.

Walchand College of Engineering, Sangli
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AY 206-27

Course Information

Programme	B. Tech. Robotics and Automation
Class, Semester	Third Year B. Tech., Sem. V
Course Code	1RA352
Course Name	Hydraulics, Pneumatics and Sensors Lab
Desired Requisites:	Elements of Robotics and Automation, Robot Drive Systems

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	-	**LA1**	**LA2**	**Lab ESE**	**Total**
Tutorial	-	30	30	40	100
Practical	2 hrs/week				
Interaction	-	**Credits: 1**			

Course Objectives

1	To develop an understanding of hydraulic and pneumatic systems
2	To enable students to design, construct, analyse, and troubleshoot fluid power circuits
3	To develop proficiency in the integration of sensors with hydraulic and pneumatic circuits

Course Outcomes (CO)

CO	Description	Blooms Taxonomy	
		Level	Descriptor
CO1	**Identify** and **recall** the functions, characteristics, and applications of hydraulic components, pneumatic components, and sensors used in industrial automation	I	Identify Recall
CO2	**Explain** the working principles and operational behaviour of hydraulic and pneumatic circuits	II	Understand
CO3	Construct, test, and simulate hydraulic and pneumatic circuits with appropriate sensor integration to achieve specified automation and motion control objectives.	III	Construct Simulate
CO4	Analyse and evaluate the performance of hydraulic and pneumatic systems	IV	Analyse Evaluate

List of Experiments / Lab Activities

List of Experiments:

Part A (Hydraulics)

1. Study of components of hydraulic circuit such as actuators, valves, accumulators, reservoirs, hoses, connectors, etc.
2. Regenerative circuit on hydraulic trainer
3. Traverse and feed circuit on hydraulic trainer
4. Study and demonstration of sensors used in hydraulic circuits
5. Construct and demonstrate industrial hydraulic circuit using simulation software such as automation studio

PART B (Pneumatics)

6. Study of components of pneumatic circuit such as actuators, valves, compressors, filters, connectors, tube, fittings, etc.
7. Speed control circuit on pneumatic trainer
8. Pneumatic circuit involving Shuttle valve/ Quick exhaust valve / Two pressure valves
9. Study and demonstration of sensors used in pneumatic circuits
10. Construct and demonstrate industrial pneumatic circuit using simulation software such as

automation studio

Text Books	
1	Oil Hydraulic Systems: Principles and Maintenance, S. R. Majumdar, Tata McGraw-Hill
2	Pneumatic Systems: Principles and Maintenance, S. R. Majumdar, Tata McGraw-Hill
3	Hydraulics and Pneumatic Controls, 2nd Edition, R Srinivasan, Tata McGraw-Hill
References	
1	*Hydraulics and Pneumatics: A Technician's and Engineer's Guide* – Andrew Parr, Butterworth-Heinemann / Elsevier
2	Sperry Vickers Industrial Hydraulics Manual
3	*Fluid Power: Hydraulics and Pneumatics,* 4th Edition, James R. Daines and Martha J. Daines, G-W Publisher
Useful Links	
1	Bosch Rexroth. WE MOVE. YOU WIN. | Bosch Rexroth India
2	Home | Parker India
3	Electrical and Industrial | Power management solutions | Eaton
4	Automation technology and technical education solutions | Festo IN
5	SMC CORPORATION | Industry Pneumatic Manufacture Actuator Control Energy saving Top maker

CO-PO Mapping													
	Programme Outcomes (PO)											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	1									1		
CO2	3	2		1						1	1		
CO3	2	2	3	3	3				2	1	1		
CO4	2	3	2	3	2	1			1	1	2		
The strength of mapping: 1:Low, 2:Medium, 3:High													

Assessment				
There are three components of lab assessment, LA1, LA2, and Lab ESE IMP: Lab ESE is a separate head of passing. Lab ESE is treated as End Semester Exam and is based on all experiments/lab activities.				
Assessment	**Based on**	**Conducted by**	**Typical Schedule**	**Marks**
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 6 Marks Submission at the end of Week 6	30
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 7 to Week 12 Marks Submission at the end of Week 12	30
Lab ESE	Lab Performance and documentation	Lab Course faculty	During Week 13 to Week 18 Marks Submission at the end of Week 18	40
Week 1 indicates the starting week of a semester. The actual schedule shall be as per the academic calendar. Lab activities/Lab performance shall include performing experiments, mini-projects, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.				

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Course Information

Programme	B.Tech. (Robotics & Automation)
Class, Semester	Third Year B. Tech., Sem. V
Course Code	1RA353
Course Name	Embedded Systems Lab
Desired Requisites:	8051 Microcontroller, Digital Electronics, C, C++ programming

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	-	**LA 1**	**LA 2**	**Lab ESE**	**Total**
Tutorial	-	30	30	40	100
Practical	2hrs/week				
Interaction	-	**Credits: 1**			

Course Objectives

1	To explain the use of Keil IDE to write program and debug the error.
2	To show the use of the development board for performing lab experiments.
3	Write Assembly, C and C++ programming to complete the lab activities.
4	Demonstrate the interfacing of embedded systems with different peripherals .

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	**Use** Keil micro-vision embedded systems IDE to debug an Assembly and C programs for the embedded system.	II	Understand
CO2	**Apply** the fundamental of Assembly Language Programing to embedded system.	III	Apply
CO3	**Write** embedded system programming in High Level Language(C, C++)	III	Apply
CO4	**Test** the Assembly, C and C++ program written in Keil IDE on development board.	IV	Analyse

List of Experiments

1. Introduction to software and hardware tool used for embedded system.
2. Assembly language program to perform different arithmetic operations, (Addition, Subtraction, Multiplication) using ARM.
3. Assembly language program to perform division operation by trail subtraction, store quotient and remainder in ARM register.
4. Assembly language program to perform data block transfer, conditional and unconditional branch instruction using ARM.
5. Assembly language program to perform Logical and Boolean operation using ARM.
6. Assembly language program to arrange the number in ascending descending order.
7. C language program for the converting hexadecimal number system to decimal number system,
8. C language program for the LED blinking using Switch.
9. C language program to merge 8 bit and 16-bit data into a single 32-bit ARM register.
10. Multiplication of Matrix A and Matrix B to produce Matrix C using ARM.
11. Interfacing DC motor and Stepper motor with ARM
12. Interfacing Keypad and touchscreen with ARM.
13. Serial port programming for UART, I2C and SPI protocols.
14. Interfacing Bluetooth and ZigBee with ARM for wireless communication.
15. C language program for Interrupt FIQ, IRQ, Non-vectored interrupt, Software interrupt.
16. Design and develop the embedded system based application.

Note:- Any 3 Assembly language, 3 C programming and 3 Interfacing experiment can be included for the lab experiment

Text Books

1	Kamal, Raj, Embedded Systems : Architecture, Programming and Design - 2nd Ed. - Tata McGraw-Hill Publishing Company Limited 2008
2	Sloss, Andrew N. & Symes, Dominic, ARM System Developers Guide Designing and Optimizing System Software - 1st Ed. - Morgan Kaufman Publication 2005
3	Furber, Steve, ARM System-On-Chip Architecture - 1st Ed. - UP Pearson India Education Services Pvt. Ltd. 2016

4	Joseph Yiu, “The Definitive Guide to ARM® Cortex®- M3 and Cortex® -M4 Processors”, 3rd Edition, UK Newnes 2014
5	Kris Schindler “Introduction to Microprocessor Based System Using the ARM Processor”
References	
1	ARM Inc., ARM Reference Manual, ARM, Inc., NA,2011
2	ARM7 / ARM® Cortex®- M3 Datasheet
3	Keil manual for the ARM7 / ARM® Cortex®- M3
4	Zurawski, R.Embedded Systems Handbook Networked Embedded Systems - 2nd Ed. - CRC Press 2009
Useful Links	
1	*www.mkp.com/companions/1558608745*
2	*www.cs.man.ac.uk/amulet/publications/books/ARMsysArch* /
3	*www.mhhe.com/kamal/emb2*
4	www.rajkamal.org /

CO-PO Mapping														
	Programme Outcomes (PO)												**PSO**	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3													
CO2	3													
CO3		3			3									
CO4			3				1							2
The strength of mapping is to be written as 1: Low, 2: Medium, 3: High Each CO of the course must map to at least one PO.														

Assessment				
There are three components of lab assessment is based on LA 1, LA 2 and Lab ESE. IMP: Lab ESE is separate head of passing. Lab ESE is treated as End Semester Exam and is based on all lab experiments/ activities.				
Assessment	**Based on**	**Conducted by**	**Typical Schedule**	**Marks**
LA 1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 6 Marks Submission at the end of Week 6	30
LA 2	Lab activities, attendance, journal	Lab Course Faculty	During Week 7 to Week 12 Marks Submission at the end of Week 12	30
Lab ESE	Lab Performance And documentation	Lab Course Faculty	During Week 13 to Week 18 Marks Submission at the end of Week 18	40
Week 1 indicates the starting week for a semester. The actual schedule shall be as per academic calendar. Lab activities/ Lab Performance shall include performing experiments, min- projects, presentation, drawings, programming and other suitable activates, as per nature and requirement of the lab course. The experimental lab shall 8-10 experiments.				

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Course Information

Programme	B. Tech. Robotics & Automation
Class, Semester	TY B. Tech., Sem. V
Course Code	1RA354
Course Name	CAD and Prototyping for Robotics Lab
Desired Requisites:	Engineering Graphics

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	-	**LA1**	**LA2**	**Lab ESE**	**Total**
Tutorial	-	30	30	40	100
Practical	2 hrs/week				
Interaction	-	**Credits: 1**			

Course Objectives

1	To train students in parametric 3D solid modeling and assembly techniques using modern CAD tools, enabling them to design custom robotic links, brackets, and mechanisms.
2	To develop proficiency in engineering graphics and technical communication by generating manufacturing-ready drawings, Bills of Materials (BOM), and applying Geometric Dimensioning & Tolerancing (GD&T).
3	To bridge the gap between digital models and physical realization by introducing the additive manufacturing pipeline, encompassing slicing software and 3D printing operations.
4	To foster an iterative engineering mindset by evaluating physical prototypes for functional adequacy, interferences, and design-for-manufacturing (DFM) constraints.

Course Outcomes (CO)

CO	Description	Blooms Taxonomy	
		Level	Descriptor
CO1	Construct fully constrained sketches and parametric 3D part models of simple mechanical and robotics components using Autodesk Fusion.	III	Applying
CO2	Generate assemblies, exploded views, BOMs, and manufacturing drawings with appropriate orthographic, sectional, and dimensioned details.	III	Applying
CO3	Analyse limits, fits, and GD&T specifications to ensure functional adequacy, assembly intent, and correct inspection requirements of a subassembly.	IV	Analysing
CO4	Evaluate the print quality of manufactured prototypes by converting CAD models into manufacturing-ready files, selecting appropriate 3D printer parameters and assessing them for iterative redesign.	V	Evaluating

List of Experiments / Lab Activities

Experiments should be based on following course contents

Module 1: Engineering drawing basics and Fusion sketching

Orthographic projection, line types, dimensioning principles, sketch constraints, fully defined sketches, reference geometry, design intent, and sketch reuse.

Module 2: Part modelling and parametric design

Extrude, revolve, sweep, loft, fillet, chamfer, shell, rib, patterns, holes, threads, user parameters, design variants, and model robustness.

Module 3: Assemblies and machine drawing

Components, joints, assembly constraints, interference check, exploded views, section views, detail views, title blocks, BOM, part drawings, assembly drawings, and drawing standards.

Module 4: Tolerances, fits and GD&T

Limits and fits, datums, feature control frames, flatness, perpendicularity, parallelism, position, profile of

a surface, and drawing-level inspection logic.
Module 5: Additive manufacturing workflow
File formats: STEP, IGES, STL, 3MF; mesh quality; STL limitations; print orientation; slicing; support strategy; layer height; wall count; infill density and pattern; nozzle temperature; bed temperature; chamber temperature; cooling; speed; warping; surface finish; dimensional error; post-print inspection.

Suggested Lab Experiments/ Activities

Phase 1: CAD Fundamentals
- Exp 1: Fusion interface, project setup, and 2D sketching with constraints. (Output: Fully constrained sketch), Basic part modelling: extrude and revolve, sweep, loft
- Exp 2: Advanced features: fillet, chamfer, shell, rib, pattern, thread.
- Exp 3: Parametric modelling using user parameters. (Output: Editable design variant)

Phase 2: Assemblies & Drawing Standards
- Exp 4: Assembly creation with joints, constraints, and interference checks.
- Exp 5: Orthographic drawings, sectional views, and detail views from a 3D model.
- Exp 6: BOM, exploded view preparation, and assembly documentation. Limits, fits, and basic GD&T on a standard machine part drawing.

Phase 3: Digital-to-Physical Robotics Pipeline
- Exp 7: Assigning mass properties and exporting an assembly as a URDF for Gazebo/ROS simulation. (Output: URDF package)
- Exp 8: Exporting STEP/STL/3MF, checking mesh quality, and DfAM (Design for Additive Manufacturing) adjustments.
- Exp 9: Slicing in Bambu Studio, configuring parameters (infill, supports), and print-test on the X1E.

Phase 4: Mini Project
- Exp 10:
  Mini-project Phase 1: Conceptualize, CAD model, apply GD&T, and slice a custom robotics end-effector.
  Mini-project Phase 2: Print, assemble, inspect, and evaluate the prototype. (Output: Prototype & Report)

Additional experiments as Below may be performed
- Advanced GD&T application on a complex robotics component (e.g., bearing housing).
- Physical Metrology & Inspection: Using calipers to measure the printed part against the GD&T drawing to assess dimensional error and warping. (Output: Inspection report)

Suggested Robotics-relevant Components/ Parts

Part	Relevance
Motor mounting bracket	Basic structural mount, hole alignment, stiffness
Sensor bracket	Compact geometry, tolerances, mounting logic
Camera/LiDAR mount	Alignment, orientation, vibration tolerance
Robot base plate	Datum selection, hole pattern, assembly logic
Link/arm segment	Lightweight design, stiffness-to-weight balance
Gripper finger	Shape optimization, contact surface design
End-effector plate	Assembly interface and bolt pattern
Bearing block / bearing housing	Fits, holes, coaxiality, sectioning
Shaft coupler / hub	Standard mechanical part with functional fit
Belt tensioner / pulley mount	Slot design, adjustment, tolerance control
Mecanum/Omni-wheel Hub	Circular Patterns" and angled extrudes/sweeps.
Heat-Set Inserts	brass heat-set inserts (designing the correct hole diameter)

Text Books	
1	N. D. Bhatt and V. M. Panchal, *Machine Drawing*, Charotar Publishing House.

2	K. L. Narayana, P. Kannaiah and K. Venkata Reddy, *Machine Drawing*, New Age International.
3	N. D. Bhatt, *Engineering Drawing*, Charotar Publishing House.
References	
1	Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing by Ian Gibson, David Rosen, and Brent Stucker (Springer).
2	ASME Y14.5 - Dimensioning and Tolerancing
3	
4	
Useful Links	
1	https://www.autodesk.com/learn/ondemand/collection/self-paced-learning-for-fusion
2	https://www.autodesk.com/learn/ondemand/course/sketching-and-part-modeling
3	https://www.autodesk.com/learn/ondemand/course/fusion360-intro-to-3d-modeling-associate
4	https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_me128
5	https://www.coursera.org/partners/autodesk
6	https://www.coursera.org/learn/packt-3d-modeling-for-3d-printing-and-laser-cutting-on-fusion-360-n8yrm
7	https://www.coursera.org/learn/3d-printing-software
8	https://wiki.bambulab.com/en/software/bambu-studio/support

CO-PO Mapping

	Programme Outcomes (PO)											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	-	2	-	3	-	-	-	-	-	-	3	-
CO2	2	-	-	-	3	-	-	-	-	3	-	2	1
CO3	3	3	2	-	-	-	-	-	-	-	-	2	1
CO4	-	2	3	2	3	-	-	-	-	-	-	3	2

The strength of mapping: 1:Low, 2:Medium, 3:High

Assessment

There are three components of lab assessment, LA1, LA2, and Lab ESE
IMP: Lab ESE is a separate head of passing. Lab ESE is treated as End Semester Exam and is based on all experiments/lab activities.

Assessment	Based on	Conducted by	Typical Schedule	Marks
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 6 Marks Submission at the end of Week 6	30
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 7 to Week 12 Marks Submission at the end of Week 12	30
Lab ESE	Lab Performance and documentation	Lab Course faculty	During Week 13 to Week 18 Marks Submission at the end of Week 18	40

Week 1 indicates the starting week of a semester. The actual schedule shall be as per the academic calendar. Lab activities/Lab performance shall include performing experiments, mini-projects, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.

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Course Information

Programme	B. Tech. Robotics & Automation
Class, Semester	TY B. Tech., Sem. V
Course Code	1VSRA345
Course Name	Mini Project - 2
Desired Requisites:	Foundational knowledge of engineering mechanics, mechanics of materials, manufacturing, machine design, robot drive systems, sensors and instrumentation, microcontroller interfacing, mechanisms, control systems, and CAD/prototyping.

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	-	**LA1**	**LA2**	**Lab ESE**	**Total**
Tutorial	-	30	30	40	100
Practical	6 hrs/week				
Interaction	-	**Credits: 3**			

Course Objectives

1	Integrate foundational knowledge from mechanical design, actuation, sensing, embedded systems, control, robot kinematics, and CAD in a multidisciplinary robotic artefact.
2	Develop a structured engineering design practice from need definition and measurable requirements through system architecture, modelling/calculation, and justified subsystem selection.
3	Provide hands-on experience in CAD, fabrication, programming, subsystem implementation, integration, calibration, and the appropriate use of modern engineering tools.
4	Cultivate predicted-vs-measured validation, systematic debugging, iterative improvement, technical documentation, teamwork, and individual ownership of engineering decisions.

Course Outcomes (CO)

CO	Description	Blooms Taxonomy	
		Level	Descriptor
CO1	Translate a provided engineering need into a clearly defined technical problem with measurable system requirements, and map major design decisions to relevant foundational courses.	L4	Analyze
CO2	Design a multidisciplinary robotic artefact integrating mechanical, actuation, sensing, embedded, and control subsystems with justified interfaces and engineering calculations.	L6	Create
CO3	Fabricate and integrate the artefact using appropriate CAD, electronics, embedded, and fabrication tools, validating individual subsystems before system integration.	L3	Apply
CO4	Evaluate system performance against design requirements through predicted-vs-measured testing, systematic debugging, and documented design improvement.	L5	Evaluate
CO5	Function effectively in a team and independently communicate and defend technical decisions, outcomes, and learning through reports, demonstrations, and viva voce.	L5	Evaluate

List of Experiments / Lab Activities

1. Course orientation, artefact-vs-application framing, team formation, selection of an artefact-based need statement/theme, and mentor allocation.

2. Problem definition, measurable requirements and success metrics; preparation of the Foundation Integration Map linking major design decisions to foundational courses.

3. Generation and comparison of system concepts; development of the complete system architecture, subsystem interfaces, and Review Gate 1 presentation.

4. Mechanical design and engineering calculations including load, force, torque, stress, material/component selection, and appropriate safety margins.

5. CAD assembly modelling, drawings, tolerances/clearances, BOM and manufacturability; actuator, drive and sensor sizing with predicted performance values.

6. Electronics, signal-chain and embedded/control planning: driver/interface circuits, I/O plan, signal conditioning, PID/state-machine/trajectory approach, and design finalization (LA1).

7. Fabrication/prototyping and parallel implementation of mechanical, sensing, actuation and embedded subsystems; calibration and independent subsystem testing.

8. Subsystem implementation review using measured test data; maintenance of a formal debugging log recording symptom, test, root cause, correction, and learning.

9. System integration and validation against defined requirements; predicted-vs-measured comparison, quantified error analysis, and at least one documented improvement/re-test cycle.

10. Final consolidation: working artefact demonstration, complete technical report and logbook, minimum three root-cause debugging cycles, individual viva, and reflection on foundational-course integration.

Indicative artefact themes: *3-DOF Robotic Arm; Closed-Loop Drive System; Fluid-Power Positioning System; Force-Modulated Gripper; Precision Positioning Table; Dead-Reckoning Localization System. Equivalent artefact-based themes may be approved when aligned with the course objectives.*

Text Books	
1	Bolton, W., Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, Pearson.
2	Lynch, K. M. and Park, F. C., Modern Robotics: Mechanics, Planning, and Control, Cambridge University Press.
3	Norton, R. L., Design of Machinery, McGraw-Hill.
References	
1	Bhandari, V. B., Design of Machine Elements, McGraw-Hill Education.
2	Craig, J. J., Introduction to Robotics: Mechanics and Control, Pearson.
3	Ogata, K., Modern Control Engineering, Pearson.
4	Fraden, J., Handbook of Modern Sensors: Physics, Designs, and Applications, Springer.
Useful Links	
1	SWAYAM / NPTEL course portal: https://swayam.gov.in and https://onlinecourses.nptel.ac.in
2	Robotics Specialization, University of Pennsylvania: https://www.coursera.org/specializations/robotics
3	Autodesk Education (Fusion): https://www.autodesk.com/education
4	Arduino Language Reference: https://www.arduino.cc/reference

CO-PO Mapping

	Programme Outcomes (PO)												PSO	
	1	2	3	4	5	6	7	8	9	10	11		1	2
CO1	2	3	1	2				1					2	1
CO2	3	2	3	1	2	1				1	1		3	2
CO3	2	1	3	1	3	1		2		2	1		3	2
CO4	1	2	2	3	2	1					1		2	2
CO5								3	3	2				

The strength of mapping: 1:Low, 2:Medium, 3:High

Assessment				
There are three components of assessment: LA1, LA2, and Lab ESE. Lab ESE is a separate head of passing and is based on the complete mini-project work. Assessment emphasizes foundation integration, design-before-build, measured validation, systematic debugging, documentation, and individual ownership rather than only the final demonstration.				
Assessment	**Based on**	**Conducted by**	**Typical Schedule**	**Marks**
LA1	Requirements & Foundation Integration Map; system architecture; design calculations; CAD/BOM; actuator/sensor selection; control/embedded plan; predicted performance.	Course Faculty / Review Panel	Weeks 2-7 Reviews 1 & 2	30
LA2	Subsystem implementation & independent testing; system integration; measured validation; debugging log; improvement/re-test evidence.	Course Faculty / Review Panel	Weeks 9-14 Reviews 3 & 4	30
Lab ESE	Working artefact; predicted-vs-measured validation; compiled debugging log; final demonstration; technical report; individual viva.	Course Faculty / Evaluation Panel	Week 15 Final Review	40
Week 1 indicates the starting week of a semester; the actual schedule shall follow the academic calendar. Mini-project activities include design reviews, engineering calculations, CAD, fabrication/prototyping, electronics and programming, subsystem testing, system integration, measurement, debugging, documentation, presentation, and viva. The structured review gates are integrated into LA1, LA2, and Lab ESE.				

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Course Information	
Programme	B. Tech. Robotics and Automation
Class, Semester	Third Year B. Tech., Sem. VI
Course Code	1RA331
Course Name	Professional Elective- 1: Introduction to Autonomous Robots
Desired Requisites:	Engineering mathematics and physics, Programming Fundamentals, Elements of Robotics & Automation

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	3Hrs / Wk	**MSE**	**ISE**	**ESE**	**Total**
Tutorial		30	20	50	100
	-	**Credits: 3**			

Course Objectives	
1	Introduce the fundamental concepts, architectures, and classifications of autonomous robots.
2	Develop understanding of different autonomous robotic platforms including humanoid, collaborative, marine, and space robots.
3	Explore ethical, safety, and cybersecurity considerations in modern robotics applications.
4	Expose students to emerging trends and future directions in autonomous robotics.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	Explain the principles, architectures, and functional components of autonomous robotic systems and their applications.	II	Understand
CO2	Apply concepts of perception, localization, mapping, navigation, and control to analyze the operation of autonomous robots in different environments.	III	Evaluate
CO3	Analyze the characteristics, capabilities, and challenges of humanoid, collaborative, marine, and space robotic systems.	IV	Apply
CO4	Evaluate emerging autonomous robotic technologies with respect to safety, security, ethical considerations, and societal impact.	V	Analyze

Module	**Module Contents**	**Hours**
I	**Fundamentals of Autonomous Robotics** Introduction to robotics and autonomous systems, Robot classifications: mobile, industrial, service, and autonomous robots, Components of autonomous robots: sensors, actuators, controllers, power systems, Robot kinematics and basic dynamics, Perception and environment modelling, Localization and mapping (SLAM basics), Path planning and navigation fundamentals	8
II	**Humanoid Robots and Collaborative Robots** Humanoid robot anatomy and biomechanics, Biped locomotion and balance control, Human-robot interaction (HRI), Applications of humanoid robots in healthcare, education, and service sectors, Collaborative robots (Cobots): concepts and characteristics, Safe human-robot collaboration and shared workspaces, Programming and deployment of cobots in Industry 4.0	8
III	**Autonomous Marine Robots**	6

	Introduction to marine robotics and underwater environments, Types of marine robots: AUVs, ROVs, USVs, Hydrodynamics and underwater locomotion, Sensing and communication challenges underwater, Navigation and localization in GPS-denied environments	
IV	**Space Robotics** Introduction to space robotics and extra-terrestrial environments, Space manipulators, rovers, and orbital robots, Motion planning and control in microgravity, Autonomous navigation for planetary exploration, Remote operation and teleoperation in space missions	6
V	**Emerging Trends in Autonomous Robotics** Swarm robotics and multi-robot systems, Cloud robotics and edge computing, Digital twins and simulation-driven robotics, Autonomous drones and aerial robotics, Soft robotics and bio-inspired robots, Future trends and research directions	6
VI	**Ethics, Safety, and Security in Autonomous Robotics** Ethical considerations in robotics and AI, Bias, transparency, and accountability in autonomous systems, Robot safety standards and regulations (ISO, ANSI, IEC), Functional safety and risk assessment, Cybersecurity challenges in connected robotic systems, Privacy and data protection issues, Social impact and workforce implications of automation, Responsible design and deployment of autonomous robots	6

Text Books	
1.	Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D., Introduction to Autonomous Mobile Robots, MIT Press, 2nd Edition, 2011.
2.	Thrun, S., Burgard, W., & Fox, D., Probabilistic Robotics, MIT Press, 2005.
3.	Spong, M. W., Hutchinson, S., & Vidyasagar, M., Robot Modeling and Control, Wiley, 2006.
4.	Craig, J. J., Introduction to Robotics: Mechanics and Control, Pearson, 4th Edition, 2018.
Reference Books	
1.	Goodrich, M. A., & Schultz, A. C., Human-Robot Interaction: A Survey, Foundations and Trends in Human-Computer Interaction, 2007.
2.	Yoshikawa, T., Foundations of Robotics: Analysis and Control, MIT Press, 1990.
Useful Links	
1.	https://see.stanford.edu/Course/CS223A
2.	https://bostondynamics.com/products/atlas/
3.	https://standards.ieee.org/initiatives/autonomous-intelligence-systems/

CO-PO Mapping													
	Programme Outcomes (PO)											**PSO**	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	2	-	-	-	-	-	-		
CO2	2	3	2	2	3	-	-	-	-	-	-		
CO3	2	3	2	3	2	-	-	-	1	1	-		
CO4	2	2	2	2	1	2	2	3	1	1	2		
The strength of mapping is to be written as 1: Low, 2: Medium, 3: High Each CO of the course must map to at least one PO.													

Assessment
The assessment is based on MSE, ISE and ESE. MSE shall be typically on modules 1 to 3. ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be

field visit, assignments etc. and is expected to map at least one higher order PO.
ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6.
For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (**ESE shall be a separate head of passing**)

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Course Information

Programme	B. Tech. (MDM - Robotics & Automation)
Class, Semester	Third Year - B. Tech., Sem. VI
Course Code	1RA332
Course Name	Power Electronics and Drives for Automation
Desired Requisites:	Basics of Analog and Digital Electronics

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	2 Hrs/week	**MSE**	**ISE**	**ESE**	**Total**
Tutorial	-	30	20	50	100
	-	**Credits: 3**			

Course Objectives

1	To establish a foundational understanding of power electronic components and their specific roles in industrial automation circuits.
2	To enable students to apply power conversion and closed-loop control strategies for DC and Servo drives used in robotic manipulation.
3	To develop the ability to analyze AC drives and Variable Frequency Drives (VFDs) for continuous processes and material handling systems.
4	To provide practical knowledge on selecting, sizing, and integrating precision drives and industrial communication protocols for complete automated architectures.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	Explain the operational principles, switching characteristics, and peripheral protection of power semiconductor devices used in automated drive panels.	II	Understand
CO2	Calculate the mathematical load dynamics of robotic manipulators and AGVs to size and select appropriate DC and Servo drive systems.	III	Apply
CO3	Analyze the speed-torque characteristics and variable frequency control strategies of AC and precision drives to match continuous material handling requirements.	IV	Analyze
CO4	Design the block-level architecture of an industrial motion control system and justify the selection of components, actuators, and communication protocols.	V	Evaluate

Module	**Module Contents**	**Hours**
I	**Power Electronic Devices in Automation Panels** The Industrial Context: Role of power electronics in factory automation, robotics, and AGVs. Semiconductor Switches: Switching characteristics and safe operating areas of power MOSFETs and IGBTs. Introduction to Intelligent Power Modules (IPMs) used in modern motor controllers. Thermal & Peripheral Considerations: Heat dissipation, snubber circuits, and solid-state relays in industrial control panels.	6
II	**Power Converters for Robotic Systems** Industrial Power Supplies: Single-phase and three-phase full-wave controlled rectifiers for DC bus generation. DC-DC Converters: Buck, Boost, and Four-Quadrant Choppers. Automation Applications: Battery management and power regulation for Autonomous Mobile Robots (AMRs), Automated Guided Vehicles (AGVs), and standalone robotic workcells.	7
III	**DC Drives & Servo Actuation**	7

	DC Motor Dynamics: Modeling of DC motors, electrical braking (regenerative and dynamic) for automated stops. DC Drive Control: PWM control and H-Bridge configurations for bidirectional motion. Industrial Servo Systems: Architecture of a servo drive. Position, velocity, and torque control loops. Feedback devices (incremental/absolute encoders, resolvers). Tuning servo drives for multi-axis robotic arms and automated assembly lines.	
IV	**AC Drives & VFDs in Material Handling** Induction Motor Dynamics: Speed-torque characteristics suited for industrial loads. Variable Frequency Drives (VFDs): Three-phase Voltage Source Inverters (VSI), SPWM techniques. V/f control strategy and vector control basics. Automation Applications: Integrating VFDs in heavy automation: continuous conveyor belts, Automated Storage and Retrieval Systems (AS/RS), and high-capacity industrial pumps.	7
V	**Precision Drives: Stepper & BLDC** Stepper Motor Drives: Variable Reluctance, Permanent Magnet, and Hybrid steppers. Micro-stepping drivers and indexing. Applications in CNC machines, 3D printing, and automated dispensing. Brushless DC (BLDC) Drives: Electronic commutation, Hall-effect sensors, and sensorless control. Automation Applications: BLDC motors in collaborative robots (Cobots), SCARA manipulators, and end-of-arm tooling (grippers).	7
VI	**Drive Integration & Industrial Protocols** Automation Integration: Interfacing electrical drives with Programmable Logic Controllers (PLCs) and Motion Controllers. Industrial Communication: Overview of fieldbuses for drives (e.g., EtherCAT, PROFINET, Modbus RTU). System Reliability: Electromagnetic Interference (EMI) mitigation in drive panels, grounding practices, and safety features (Safe Torque Off - STO) in modern industrial drives.	6

Text Books	
1	**Hughes, A., & Drury, B. (2019).** *Electric Motors and Drives: Fundamentals, Types and Applications* (5th ed.). Newnes.
2	**Rashid, M. H. (2014).** *Power Electronics: Circuits, Devices, and Applications* (4th ed.). Pearson.
3	**Bose, B. K. (2001).** *Modern Power Electronics and AC Drives*. Prentice Hall.
References	
1	**Dubey, G. K. (2001).** *Fundamentals of Electrical Drives* (2nd ed.). Narosa Publishing House.
2	**Leonhard, W. (2001).** *Control of Electrical Drives* (3rd ed.). Springer. *(A deeper dive into the control theory behind servo mechanisms).*
3	**Kilian, C. T. (2005).** *Modern Control Technology: Components and Systems* (3rd ed.). Delmar Cengage Learning. *(Great for understanding how drives interface with PLCs and overall automation systems).*
Useful Links	
1	https://nptel.ac.in/courses/108104140
2	training.ti.com
3	
4	

	Program Outcomes										
CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	3	2	-	-	-	-	-	-	-	-	-
CO2	3	2	2	-	2	-	-	-	-	-	-
CO3	2	3	2	2	2	1	-	-	-	-	-
CO4	1	2	3	2	3	2	1	-	-	-	2

Assessment
The assessment is based on MSE, ISE and ESE. MSE shall be typically on modules 1 to 3. ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO. ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6. For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (ESE shall be a separate head of passing)

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Course Information	
Programme	B. Tech. Robotics and Automation
Class, Semester	Third Year B. Tech., Sem. VI
Course Code	1RA333
Course Name	Professional Elective- 1: Robot Operating Systems (ROS) and Middleware
Desired Requisites:	Python, C++ basics, ROS Lab

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	3Hrs / Wk	**MSE**	**ISE**	**ESE**	**Total**
Tutorial		30	20	50	100
	-	**Credits: 3**			

Course Objectives

1	To introduce the concepts of robotic middleware and the role of Robot Operating Systems (ROS/ROS2) in the development of intelligent robotic systems.
2	To develop understanding of ROS architecture, communication mechanisms, software packages, and system integration techniques.
3	To familiarize students with robot modelling, visualization, simulation, localization, and navigation frameworks using ROS.
4	To expose students to advanced robotic software architectures including multi-robot systems, cloud robotics, and emerging middleware technologies.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	Explain the architecture, components, and communication mechanisms of ROS/ROS2-based robotic systems.	II	Explain
CO2	Apply ROS tools and middleware services for robot software development, communication, and system integration.	III	Apply
CO3	Analyze robot models, simulation environments, localization, and navigation frameworks used in robotic applications.	IV	Analyze
CO4	Evaluate robotic software architectures and recommend suitable middleware solutions for multi-robot, cloud-connected, and autonomous robotic systems.	V	Evaluate

Module	**Module Contents**	**Hours**
I	**Introduction to Robot Software Systems and Middleware** Evolution of robot software systems, need for middleware in robotics, Distributed robotic architectures, Robot Operating System: history and ecosystem, ROS vs ROS2, Open-source robotics frameworks, Industrial applications of robotic middleware	6
II	**ROS Architecture and Development Environment** ROS computational graph, Nodes, topics, messages and services, Actions and parameters, Packages and workspaces, ROS command-line tools, Launch files and package management, Introduction to colcon and ROS2 development workflow	7
III	**Communication, Data Exchange and System Integration** Publisher–subscriber communication, Client–server architecture, DDS-based communication in ROS2, Interfacing sensors and actuators, Robot state representation, Data logging and rosbag, System integration methodologies	7
IV	**Robot Modelling, Visualization and Simulation** URDF and XACRO, Kinematic representation of robots, RViz visualization,	7

	Gazebo simulation environment, Robot simulation workflows, Digital twins and virtual testing, Simulation-based validation	
V	**Navigation, Localization and Perception Frameworks** Mobile robot software architecture, TF transformations, Localization concepts, Mapping and SLAM frameworks, Navigation stack, Sensor fusion concepts, Perception pipelines and camera integration	7
VI	**ROS2 and Middleware** Multi-robot systems, Cloud and edge robotics, Lifecycle management, Real-time considerations, Cybersecurity in robotic systems, Case studies from industrial and service robotics, Future trends in robot software ecosystems	6

Text Books	
5.	Programming Robots with ROS, Morgan Quigley, Brian Gerkey and William Smart, O'Reilly.
6.	Robot Operating System (ROS): The Complete Reference, Anis Koubaa, Springer.
7.	ROS Robotics by Example, Morgan Quigley et al., Packt.
Reference Books	
3.	ROS2 from Scratch, Aubrey Kagan.
4.	Artificial Intelligence for Robotics, John Hunt,
5.	Springer Handbook of Robotics, Siciliano and Khatib.
6.	Introduction to Autonomous Mobile Robots, Roland Siegwart, Illah Nourbakhsh and Davide Scaramuzza.
Useful NPTEL Courses	
4.	Robotics – Prof. D. K. Pratihar, IIT Kharagpur.
5.	Experimental Robotics – Prof. D. K. Pratihar, IIT Kharagpur.
6.	Mobile Robotics (where available in current NPTEL offerings)
7.	Advanced Robotics – Prof. Ashish Dutta, IIT Kanpur.

CO-PO Mapping

	Programme Outcomes (PO)											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	2	-	-	-	-	-	-		
CO2	2	3	2	-	3	-	-	-	1	1	-		
CO3	2	3	2	3	3	-	-	-	-	-	-		
CO4	2	3	3	2	3	-	-	-	1	1	2		

The strength of mapping is to be written as 1: Low, 2: Medium, 3: High
Each CO of the course must map to at least one PO.

Assessment

The assessment is based on MSE, ISE and ESE.
MSE shall be typically on modules 1 to 3.
ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO.
ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6.
For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (**ESE shall be a separate head of passing**)

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Course Information	
Programme	B. Tech. - Robotics & Automation
Class, Semester	Third Year - B. Tech., Sem. VI
Course Code	1RA321
Course Name	PLC programming
Desired Requisites:	Elements of Robotics and Automation, Physics, Basics of Electronics

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	2 Hrs/week	**MSE**	**ISE**	**ESE**	**Total**
Tutorial	-	30	20	50	100
	-	**Credits: 3**			

Course Objectives

1	To impart foundational knowledge regarding the architecture, hardware components, and operational scan cycles of Programmable Logic Controllers in industrial automation.
2	To develop the students' ability to formulate and design conceptual ladder logic sequences using basic and advanced instructions for controlling robotic cells and manufacturing processes.
3	To introduce the theoretical principles of integrating PLCs with industrial field devices, safety mechanisms, drives, and standard communication networks.
4	To provide analytical frameworks for systematic troubleshooting, fault diagnosis, and proper documentation of PLC-based automated systems through industrial case studies.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	Explain the architecture, hardware components, and fundamental scan cycle concepts of Programmable Logic Controllers in industrial automation.	II	Understand
CO2	Illustrate the theoretical interfacing and integration of PLCs with discrete/analog I/O, motor drives, safety devices, and industrial communication networks.	III	Apply
CO3	Analyze automation system faults through case studies to determine appropriate PLC troubleshooting methodologies and structured documentation practices.	IV	Analyze
CO4	Formulate conceptual ladder logic sequences utilizing timers, counters, and advanced instructions to solve industrial machine control and robotic cell problems.	VI	Create

Module	**Module Contents**	**Hours**
I	**Introduction to Automation and PLC Architecture** Need for industrial automation; evolution from relay logic to PLC; role of PLC in manufacturing and robotics; advantages and limitations of PLC; PLC versus microcontroller and hardwired control; PLC versus Robot Controller; basic PLC system block diagram; CPU, memory, power supply, input modules, output modules, and programming device; PLC scan cycle; input scan, program execution, output update; PLC operating modes; basic installation and mounting concepts; industrial applications of PLC in machine tools, conveyors, material handling, and robotic workcells.	5
II	**Ladder Logic Fundamentals and Basic Instructions** IEC-style introduction to PLC programming; ladder diagram symbols; normally open and normally closed contacts; coils; Boolean logic in ladder form; AND, OR, NOT implementations; internal relays and memory bits; sealing circuits;	5

	latch and unlatch instructions; timers: ON-delay, OFF-delay, retentive timers; counters: up counter and down counter; basic sequence control; start-stop circuits; interlocking logic; alarm indication circuits; traffic light control; water tank filling and pumping logic; motor starter control; handshake logic between a PLC and a robotic manipulator; pneumatic gripper sequence control.	
III	**PLC Programming for Industrial Control** Advanced ladder logic concepts; set/reset logic; one-shot instructions; edge detection; jump and master control instructions; shift registers; bit manipulation; compare instructions; arithmetic operations; move instructions; data file concepts; word and register handling; program structuring; sequential control of machines; step-by-step automation logic; error handling and safety interlocks; introduction to structured design of PLC programs; typical programs for conveyor sorting, pick-and-place sequencing, batch filling, and machine cycle control.	5
IV	**PLC Hardware, Wiring, and Industrial Interfacing** Discrete input devices: push buttons, limit switches, proximity sensors, photoelectric sensors; output devices: relays, contactors, solenoid valves, lamps, buzzers; PLC wiring practices; sourcing and sinking concept; interface relays; isolation; basic industrial signal types; introduction to analog I/O; signal conditioning; temperature, pressure, and level input interfacing at the PLC level; motor starter and VFD interface basics; safety devices such as emergency stop safety relays, light curtains, zone scanners and interlock circuits; grounding and noise considerations; installation, commissioning, and maintenance.	5
V	**PLC Networking and Industrial Communication Basics** Need for PLC communication in automation systems; PLC communication concept; point-to-point and networked control; serial communication basics; RS-232 and RS-485 overview; introduction to Modbus RTU and Modbus TCP; industrial Ethernet concepts; introduce PROFINET and EtherCAT**;** PLC-to-PLC communication; fieldbus idea; networked sensors, actuators, and controllers; distributed control concept at a basic level; communication diagnostics; introduction to remote I/O; reliability and fault tolerance in communication links.	5
VI	**PLC Applications, Troubleshooting, and Case Studies** PLC-based automation applications in robotics and manufacturing; conveyor control systems; bottle filling and packaging; automatic sorting; material handling systems; pumping station logic; machine tool automation; pick-and-place and palletizing logic; sequence control of robotic workcell auxiliaries; troubleshooting methodology; fault diagnosis; online and offline debugging; documentation practice; maintenance and preventive checks; case studies from discrete manufacturing and automation cells; introduction to production control systems and the role of PLC in factory automation.	5

Text Books	
1	Jadhav, V. R. *Programmable Logic Controller*. Khanna Publishers, 2017.
2	Mitra, Madhuchhanda, and Samarjit Sengupta. *Programmable Logic Controllers and Industrial Automation: An Introduction*. 2nd ed., Penram International Publishing, 2017.
3	Petruzella, Frank D. *Programmable Logic Controllers*. 6th ed., McGraw Hill India, 2023.
References	
1	Bolton, W. *Programmable Logic Controllers*. 6th ed., Newnes/Elsevier, 2015.
2	Webb, John W., and Ronald A. Reis. *Programmable Logic Controllers: Principles and Applications*. 5th ed., Prentice Hall, 2002.
Useful Links	
1	nptel.ac.in/courses/108105062

	Program Outcomes										
CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**

CO1	3	1	-	-	-	-	-	-	-	-	1
CO2	3	2	2	-	-	-	-	-	-	-	-
CO3	3	2	2	-	-	1	-	-	-	-	1
CO4	3	3	1	1	-	1	-	1	-	1	1

Assessment
The assessment is based on MSE, ISE and ESE. MSE shall be typically on modules 1 to 3. ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO. ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6. For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (ESE shall be a separate head of passing)

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Course Information

Programme	B. Tech. Robotics and Automation
Class, Semester	Third Year B. Tech., Sem. VI
Course Code	1RA322
Course Name	AIML for Robotics
Desired Requisites:	Basic programming (Python), linear algebra basics, probability fundamentals

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	3Hrs / Wk	**MSE**	**ISE**	**ESE**	**Total**
Tutorial		30	20	50	100
	-	**Credits: 3**			

Course Objectives

1	Introduce core AI concepts used in autonomous robotic systems.
2	Develop understanding of knowledge representation, search, planning, uncertainty, and decision making.
3	Teach supervised and unsupervised ML methods relevant to robotic perception, localization, diagnostics, and control.
4	Prepare students for advanced topics such as SLAM, reinforcement learning, deep learning, and robot learning.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	Explain the core paradigms of AI/ML, the perception-planning-action loop, logic-based knowledge representations, and the fundamental trade-offs between symbolic planning and data-driven policies in robotics.	II	Understand
CO2	Apply classical search algorithms (A∗, DFS, BFS) and machine learning workflows (data cleaning, normalization, pipelines) to solve grid-map robot navigation and data preprocessing challenges.	III	Apply
CO3	Analyze robotic sensor data and diagnostics logs using statistical modeling, dimensionality reduction (PCA), and supervised learning to diagnose wheel-slip, detect anomalies, and classify motor faults.	IV	Analyze
CO4	Evaluate the performance, safety, latency, and computational memory footprint of different AI/ML models to select the most robust deployment strategy for real-time robotic control and decision-making.	V	Evaluate

Module	**Module Contents**	**Hours**
I	**AI Foundations for Robotics** What is AI? Symbolic AI vs data-driven AI; robotics perspective, Intelligent agents, perception–planning–action loop, State-space formulation of robotic problems, Classical search: BFS, DFS, Uniform Cost Search, A*, Heuristics, admissibility, completeness, optimality, Case study: grid-map robot navigation.	6
II	**Search, Planning, and Decision Making** Local search, hill climbing, simulated annealing (conceptual), Constraint satisfaction problems (CSPs) and robot task assignment, Planning concepts: STRIPS/PDDL overview, Finite-state machines and behaviour trees for robot	7

	behaviour, Introduction to Markov Decision Processes (MDPs) and policies, Trade-offs between symbolic planning and learned policies.	
III	**Knowledge Representation and Uncertainty** Propositional and first-order logic basics, Rules, ontologies, semantic representations (robotics examples)., Probabilities, conditional probability, Bayes' rule., Bayesian networks and sensor fusion intuition., Hidden state estimation overview: Bayes filter, Kalman filter intuition, particle filter intuition., localization, fault detection, perception uncertainty.	7
IV	**ML Foundations and Data Pipeline** What is machine learning? Supervised vs unsupervised learning., Robotics datasets: IMU, encoder, lidar features, camera-derived features, diagnostics logs., Data cleaning, missing values, outliers, normalization/standardization., Train/validation/test splits and data leakage., Feature engineering for time-series and sensor data., scikit-learn workflow: pipelines and reproducibility.	6
V	**Supervised Learning for Robotics** Linear regression and regularization, Logistic regression for classification., k-NN, decision trees, random forests (basic usage)., Model evaluation: MAE/MSE/RMSE, accuracy, precision, recall, F1, ROC-AUC., Cross-validation, confusion matrix, overfitting/underfitting. obstacle class prediction, wheel-slip detection, motor fault classification.	7
VI	**Unsupervised Learning and Intermediate Topics** Clustering: k-means, DBSCAN intuition and use cases., Dimensionality reduction: PCA for sensor feature compression., Anomaly detection concepts for robot health monitoring., Model selection and deployment considerations (latency, memory, safety)., Ethics, bias, robustness, and safety in AI-enabled robots. Deep learning, reinforcement learning, SLAM, imitation learning.	7

Text Books	
8.	Artificial Intelligence: A Modern Approach, Stuart Russell & Peter Norvig, 4th ed., Pearson.
9.	Introduction to Machine Learning with Python, Andreas C. Müller & Sarah Guido, O'Reilly.
10.	Probabilistic Robotics, Sebastian Thrun, Wolfram Burgard & Dieter Fox, MIT Press.
11.	Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Peter Corke, 2nd ed., Springer.
Reference Books	
7.	Pattern Recognition and Machine Learning- Author: Christopher M. Bishop, Publisher: Springer Publication year: 2006, Subject area: Machine learning, pattern recognition, probabilistic modeling
8.	Modern Robotics: Mechanics, Planning, and Control- Authors: Kevin M. Lynch, Frank C. Park Publisher: Cambridge University Press First edition: May 25, 2017 (Reissued 2024)
Useful Links	
8.	https://docs.python.org/3/tutorial
9.	https://numpy.org/doc/stable/user/quickstart.html
10.	https://pandas.pydata.org/docs/getting_started/index.html
11.	https://matplotlib.org/stable/users/getting_started/
12.	https://scikit-learn.org/stable/user_guide.html

CO-PO Mapping													
	Programme Outcomes (PO)											**PSO**	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	2	-	-	-	-	-	-	-	-	-		
CO2	3	2	2	-	3	-	-	-	2	1	-		
CO3	3	3	2	3	3	-	-	-	2	1	-		

CO4	2	3	3	2	2	2	1	3	2	2	2		

The strength of mapping is to be written as 1: Low, 2: Medium, 3: High
Each CO of the course must map to at least one PO.

Assessment
The assessment is based on MSE, ISE and ESE. MSE shall be typically on modules 1 to 3. ISE shall be taken throughout the semester in the form of teacher's assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO. ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6. For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (**ESE shall be a separate head of passing**)

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AY 2026-27

Course Information

Programme	B. Tech. (Robotics & Automation)
Class, Semester	Third Year - B. Tech., Sem. VI
Course Code	1RA323
Course Name	Robot Kinematics and Dynamics
Desired Requisites:	Fundamentals of robotics, mathematics, Mechanism for Robotics and automation

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	3 Hrs/week	**MSE**	**ISE**	**ESE**	**Total**
Tutorial	-	30	20	50	100
	-	**Credits: 3**			

Course Objectives

1	Understand industrial robot structures and their kinematic modelling.
2	Apply mathematical tools for robot position, orientation, velocity and motion planning.
3	Analyse robot mechanism behaviour using forward/inverse kinematics, Jacobians, and dynamics.
4	Evaluate robot motion trajectories, control fundamentals, and workspace characteristics.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO	**Course Outcome Statement/s**	**Bloom's Taxonomy Level**	**Bloom's Taxonomy Description**
CO1	Understand relationship between joint space and Cartesian space	II	Understanding
CO2	Apply mathematics for manipulator positioning and motion planning	III	Applying
CO3	Analyse robot mechanisms using kinematics and dynamics principles	IV	Analysing
CO4	Evaluate robot trajectories and motion behaviour in controlled environments	V	Evaluating

Module	**Module Contents**	**Hours**
I	**Spatial descriptions and Mathematical Preliminaries** Coordinate frames, Rotation matrices, Homogeneous transformation matrices, Representation of positions & orientations. Manipulator structure: links, joints, kinematic chains.	5
II	**Forward Kinematics** Denavit-Hartenberg (D-H) parameters, frame assignment rules. FK of common simple robots (2R, 3R, SCARA). Conceptual workspace characteristics.	8
III	**Inverse Kinematics** Manipulator geometry and constraints. Geometric and algebraic IK methods for planar (2R, 3R) and SCARA manipulators. Workspace limits.	7
IV	**Velocity Kinematics & Jacobians** Linear and angular velocities of links, the Jacobian matrix, velocity propagation. Mapping joint rates to end-effector velocities. Conceptual interpretation of singularities.	8
V	**Module IV – Introduction to Dynamics** Kinetic & potential energy, Lagrange-Euler formulation. Dynamic equations of simple manipulators (e.g., 2R). Conceptual overview of inertia, Coriolis, and gravity terms. Actuator friction and gearing basics.	7
VI	**Module V – Introduction to Trajectory Planning** Path vs. trajectory, joint-space planning. Linear and cubic polynomial trajectories. Trapezoidal Velocity Profile (LSPB).	5

Text Books	
1	D.Nagrath and Mittal, “Robotics and Control”, Tata McGraw-Hill, 2003
2	John Craig, “Introduction to Robotics: Mechanics and Control”, Pearson Prentice Hall Pearson Education
3	Spong and Vidhyasagar, “Robot Dynamics and Control”, John Wiley and sons, 2008
4	Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, 2019
References	
1	Lynch, K. M., & Park, F. C. (2017). Modern Robotics: Mechanics, Planning, and Control. Cambridge University Press
2	Harry Asada and Slottine “Robot Analysis and Control”, Wiley Publications, 2014
3	S K Saha, “Introduction to Robotics”, 2nd edition, TMH, 2013
4	S. B. Niku, Introduction to Robotics – Analysis, Contro, Applications, 3rd edition, John Wiley & Sons Ltd., 2020
Useful Links	
1	https://ocw.mit.edu/courses/mechanical-engineering/2-12-introduction-to-robotics-fall-2005/lecture-notes/
2	https://www.ni.com/en-us/innovations/instrumentation.html
3	https://www.coursera.org/learn/modernrobotics-course2
4	https://www.youtube.com/watch?v=Tf_DsOcCgio

	Program Outcomes												
CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PSO1**	**PSO2**
CO1	3	2	-	-	-	-	-	-	-	-	1	2	-
CO2	3	3	2	-	2	-	-	-	-	-	1	3	1
CO3	3	3	-	2	2	-	-	-	-	-	1	3	2
CO4	2	3	3	2	2	-	-	-	-	-	1	3	2

Assessment

The assessment is based on MSE, ISE and ESE.
MSE shall be typically on modules 1 to 3.
ISE shall be taken throughout the semester in the form of teacher’s assessment. Mode of assessment can be field visit, assignments etc. and is expected to map at least one higher order PO.
ESE shall be on all modules with around 40% weightage on modules 1 to 3 and 60% weightage on modules 4 to 6.
For passing a theory course, Min. 40% marks in (MSE+ISE+ESE) are needed and Min. 40% marks in ESE are needed. (ESE shall be a separate head of passing)

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Course Information

Programme	B. Tech. Robotics and Automation
Class, Semester	Third Year B. Tech., Sem. VI
Course Code	1RA371
Course Name	AIML for Robotics Lab
Desired Requisites:	Basic Programming (Python), Fundamentals of Robotics, Linear Algebra and Probability Basics

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	-	**LA1**	**LA2**	**Lab ESE**	**Total**
Tutorial	-	30	30	40	100
Practical	2 hrs/week				
Interaction	-	**Credits: 1**			

Course Objectives

1	To introduce students to fundamental Artificial Intelligence techniques used in robotic systems, including intelligent agents, search algorithms, path planning, and knowledge-based systems.
2	To develop skills in computer vision and machine learning techniques for robot perception, decision-making, and autonomous operation.
3	To enable students to collect, preprocess, analyse, and interpret robotic sensor data using appropriate machine learning methods.
4	To provide hands-on experience in developing AI and ML-based robotic solutions for solving real-world automation and robotics problems.

Course Outcomes (CO)

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

CO	Description	Blooms Taxonomy	
		Level	Descriptor
CO1	Explain the concepts of intelligent agents, search algorithms, path planning, knowledge representation, and machine learning techniques used in robotic systems.	II	Understand
CO2	Apply artificial intelligence and machine learning algorithms to perform robot navigation, object detection, classification, prediction, and clustering tasks.	III	Apply
CO3	Analyse robotic sensor data and evaluate the performance of AI/ML models for decision-making, fault detection, and autonomous operation.	IV	Analyze
CO4	Design and develop AI/ML-based robotic solutions to address real-world automation and robotics problems through mini-project implementation.	V	Evaluate

List of Experiments / Lab Activities

List of Experiments:

PART A (Artificial Intelligence for Robotics)

5. Intelligent Agent Design for Robotics
6. Search Algorithms for Robot Navigation
7. Path Planning using A* Algorithm
8. Knowledge Representation and Expert Systems
9. Computer Vision for Object Detection

PART B (Machine Learning for Robotics)

11. Data Collection and Pre-processing for Robotics
12. Robot State Prediction using Linear Regression
13. Object Classification using K-Nearest Neighbour (KNN)
14. Robot Fault Detection using Decision Trees
15. Clustering of Sensor Data using K-Means

Note: Suggested mini projects –

1) AI-Based Obstacle Avoidance Robot
2) Intelligent Line Following Robot
3) Object Recognition and Sorting Robot
4) Predictive Maintenance System for Industrial Robots
5) Human Detection and Tracking Robot
6) Smart Warehouse Navigation Robot

Text Books	
1	Artificial Intelligence: A Modern Approach – Stuart Russell and Peter Norvig., Pearson, 2020
2	Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow. Aurélien Géron Publisher: O'Reilly Media First edition: 2017
3	Introduction to Artificial Intelligence and Expert Systems., Dan W. Patterson, Prentice Hall
References	
1	Introduction to Machine Learning with Python: A Guide for Data Scientists, Andreas C. Müller & Sarah Guido: O'Reilly Media First published: 2016
2	Learning Robotics using Python , Author: Lentin Joseph First published: 2015 (Packt Publishing)
Useful Links	
1	https://www.kaggle.com/datasets
2	https://www.openml.org/
3	https://developers.google.com/machine-learning/crash-course

CO-PO Mapping													
	Programme Outcomes (PO)											**PSO**	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	2	-	-	-	-	-	-		
CO2	3	3	2	2	3	-	-	-	-	-	-		
CO3	2	3	2	3	3	-	-	-	1	-	-		
CO4	2	3	3	3	3	1	-	-	2	1	2		
The strength of mapping: 1: Low, 2: Medium, 3: High													

Assessment

There are three components of lab assessment, LA1, LA2, and Lab ESE
IMP: Lab ESE is a separate head of passing. Lab ESE is treated as End Semester Exam and is based on all experiments/lab activities.

Assessment	**Based on**	**Conducted by**	**Typical Schedule**	**Marks**
LA1	Lab activities, attendance, journal, Mini Project	Lab Course Faculty	During Week 1 to Week 6 Marks Submission at the end of Week 6	30
LA2	Lab activities, attendance, journal, Mini Project	Lab Course Faculty	During Week 7 to Week 12 Marks Submission at the end of Week 12	30
Lab ESE	Lab Performance	Lab Course	During Week 13 to Week 18	40

	and documentation, Mini Project	faculty	Marks Submission at the end of Week 18	

Week 1 indicates the starting week of a semester. The actual schedule shall be as per the academic calendar. Lab activities/Lab performance shall include performing experiments, mini-projects, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.

Walchand College of Engineering, Sangli
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AY 2026-27

Course Information

Programme	B. Tech. Robotics & Automation
Class, Semester	TY B. Tech., Sem. VI
Course Code	1RA372
Course Name	PLC programming Lab
Desired Requisites:	Elements of Robotics and Automation, Physics, Basics of Electronics

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	-	**LA1**	**LA2**	**Lab ESE**	**Total**
Tutorial	-	30	30	40	100
Practical	2 hrs/week				
Interaction	-	**Credits: 1**			

Course Objectives

1	To introduce the hardware wiring, configuration, and practical execution of hardwired relay logic versus programmable control.
2	To develop hands-on programming proficiency in ladder logic, utilizing basic and advanced instructions to solve industrial sequence control problems.
3	To train students in interfacing PLCs with standard mechatronic field devices, including electro-pneumatic actuators, motor drives, and industrial sensors.
4	To enable the simulation and validation of automated sequences for robotic workcells, material handling, and process control using modern automation software.

Course Outcomes (CO)

CO	Description	Blooms Taxonomy	
		Level	Descriptor
CO1	Construct hardwired relay logic circuits and translate them into fundamental PLC ladder diagrams for motor control.		Apply
CO2	Interface PLCs with electro-pneumatic systems, variable frequency drives, and industrial sensors for synchronized machine actuation.		Apply
CO3	Develop sequential PLC programs using timers, counters, and comparators to automate multi-state industrial control tasks.	VI	Create
CO4	Simulate and validate robotic cell handshake logic and material sorting operations using modern PLC programming environments and simulation tools.	VI	Create

List of Experiments / Lab Activities

1. Relay Logic Control: Demonstration and hardwired development of basic relay logic circuits (AND, OR, NOT logic using physical relays).
2. Motor Control & Latching: Design and implementation of a motor start-stop circuit with latching (sealing) logic using both hardwired components and PLC software.
3. Traffic Control System: Development and execution of timer-based ladder logic for a multi-way road crossing traffic light sequence.
4. Tank water Level Management: Programming a water level controller using sensor inputs to sequence inlet/outlet pumps and trigger alarms based on level thresholds.
5. Elevator Control Sequence: Programming the logic for a multi-floor lift/elevator system, utilizing limit switches, door timers, and floor call memory blocks.
6. Vending Machine Logic: Development of a program using up/down counters and data comparators to simulate vending machine operation (coin counting and product dispensing).
7. Automated Object Detection: Wiring and programming logic to differentiate objects using a combination of inductive, capacitive, and photoelectric sensors.
8. Conveyor Control System: Integrating digital sensors to sequence a material handling conveyor (start, stop on detection, and batch counting).

9. Electro-Pneumatic Sequence Control: Programming a multi-cylinder cascade sequence (e.g., A+ B+ A- B-) using PLC outputs to trigger solenoid valves and reed switches for positional feedback.
10. Automated Sorting Station: Integrating sensors and pneumatic cylinders on a gravity chute to sort metallic and non-metallic materials into respective bins.
11. VFD Interfacing: Connecting a PLC to a Variable Frequency Drive (VFD) to control the speed and direction of a 3-phase AC motor via digital and analog signals.
12. HMI Integration: Programming an industrial Human Machine Interface (HMI) screen to monitor PLC data tags, start/stop a process, and display machine fault alarms.
13. Robotic Pick-and-Place Workcell Simulation: Simulating the sequence logic, safety interlocks, and hardware handshake signals required between a PLC and a robotic manipulator.

(Instructors may select 8-10 experiments from the above list).

Text Books	
1	Jadhav, V. R. *Programmable Logic Controller*. Khanna Publishers, 2017.
2	Mitra, Madhuchhanda, and Samarjit Sengupta. *Programmable Logic Controllers and Industrial Automation: An Introduction*. Penram International Publishing, 2015.
3	Petruzella, Frank D. *Programmable Logic Controllers*. 5th ed., McGraw-Hill Education, 2016.
References	
1	Bolton, W. *Programmable Logic Controllers*. 6th ed., Elsevier/Newnes, 2015.
2	Hackworth, John R., and Frederick D. Hackworth. *Programmable Logic Controllers: Programming Methods and Applications*. Pearson Education, 2004.
3	Rehg, James A., and Glenn J. Sartori. *Programmable Logic Controllers*. 3rd ed., Pearson Education, 2019.
Useful Links	
1	ial-coep.vlabs.ac.in
2	nptel.ac.in/courses/108105088
3	plcfiddle.com

CO-PO Mapping														
	Programme Outcomes (PO)												**PSO**	
	1	2	3	4	5	6	7	8	9	10	11		1	2
CO1	3	2	1	-	2	-	-	-	1	1	-			
CO2	3	3	3	1	3	-	-	-	1	1	-			
CO3	3	2	3	2	3	-	-	-	2	1	-			
CO4	3	2	3	2	3	-	-	-	2	2	-			
The strength of mapping: 1:Low, 2:Medium, 3:High														

Assessment

There are three components of lab assessment, LA1, LA2, and Lab ESE
IMP: Lab ESE is a separate head of passing. Lab ESE is treated as End Semester Exam and is based on all experiments/lab activities.

Assessment	**Based on**	**Conducted by**	**Typical Schedule**	**Marks**
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 5 Marks Submission at the end of Week 5	30
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 7 to Week 11 Marks Submission at the end of Week 11	30
Lab ESE	Lab Performance and documentation	Lab Course faculty	During Week 12 to Week 13 Marks Submission at the end of Week 13	40

Week 1 indicates the starting week of a semester. The actual schedule shall be as per the academic calendar. Lab activities/Lab performance shall include performing experiments, mini-projects, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.

Walchand College of Engineering, Sangli
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AY 2025-26

Course Information

Programme	B. Tech. Robotics & Automation
Class, Semester	TY B. Tech., Sem. VI
Course Code	1RA373
Course Name	Robot Kinematics and Dynamics Lab
Desired Requisites:	Fundamentals of robotics, mathematics, Mechanism for Robotics and automation

Teaching Scheme		**Examination Scheme (Marks)**			
Lecture	-	**LA1**	**LA2**	**Lab ESE**	**Total**
Tutorial	-	30	30	40	100
Practical	2 hrs/week				
Interaction	-	**Credits: 1**			

Course Objectives

1	To introduce the mathematical foundations of spatial geometry, homogeneous transformations, and the standard Denavit-Hartenberg (DH) convention for modeling robot architectures.
2	To develop the analytical and computational skills required to formulate and solve the forward and inverse kinematic models of multi-DOF serial manipulators.
3	To impart knowledge of differential kinematics, utilizing Jacobian matrices to evaluate robot velocities, static payload forces, and kinematic singularities.
4	To familiarize students with motion control principles to generate smooth, constrained task-space and joint-space trajectories.

Course Outcomes (CO)

CO	Description	Blooms Taxonomy	
		Level	Descriptor
CO1	Formulate and computationally implement spatial transformations and Denavit-Hartenberg (DH) parameters for standard industrial robot architectures.	III	Applying
CO2	Compute and simulate the forward and inverse kinematics of serial manipulators to determine end-effector pose and required joint parameters.	IV	Analysing
CO3	Model the rigid-body dynamics of robotic manipulators to calculate requisite joint torques for simulation and control purposes.	IV	Analysing
CO4	Evaluate the differential motion, static forces, and singularities of robotic manipulators using Jacobian matrices.	V	Evaluating

List of Experiments / Lab Activities

Experiments are to be Based on Spatial Geometry & Structural Architecture, Forward & Inverse Kinematics, Trajectory Planning, Differential Kinematics & Statics, Dynamic Modeling, using software tools such as RoboAnalyzer, RoboDK, Robotics Toolbox for Python

List of Experiments: (10 experiments)
Familiarization with RoboAnalyzer
Familiarization with RoboDK and Robotics Toolbox for Python
DH Parameter Assignment for Planar Robots (2R, 3R)
Forward Kinematics of Planar Robots (2R and 3R)
Forward Kinematics of a 6-DOF Spatial Robot (PUMA 560)
Workspace Visualization and Reachability Analysis

Inverse Kinematics of a 2R Planar Robot — Geometric Method Inverse Kinematics of 6-DOF Robot — Multiple Configurations Jacobian Matrix and Velocity Analysis Singularity Analysis and Manipulability Measure Joint-Space Trajectory Planning — Polynomial Interpolation Cartesian-Space Trajectory Planning and Path Simulation Newton-Euler Dynamics — Joint Torque Computation Lagrangian Dynamics — Equations of Motion and Simulation Integration Exercise — Pick-and-Place Task Simulation

Text Books	
1	Craig, J. J. (2018). *Introduction to Robotics: Mechanics and Control* (4th Ed.). Pearson.
2	Saha, S. K. (2014). *Introduction to Robotics* (2nd Ed.). McGraw-Hill Education.
3	Corke, P. (2017). *Robotics, Vision and Control: Fundamental Algorithms in Python* (1st/2nd Ed.). Springer.
References	
1	Siciliano, B., Sciavicco, L., Villani, L., & Oriolo, G. (2010). *Robotics: Modelling, Planning and Control*. Springer.
2	Spong, M. W., Hutchinson, S., & Vidyasagar, M. (2020). *Robot Modeling and Control* (2nd Ed.). Wiley.
3	Ghosal, A. (2006). *Robotics: Fundamental Concepts and Analysis*. Oxford University Press.
4	
Useful Links	
1	https://petercorke.github.io/robotics-toolbox-python/
2	https://docs.sympy.org/latest/index.html
3	http://www.roboanalyzer.com/
4	https://mr-iitkgp.vlabs.ac.in/exp/movemaster/theory.html
5	https://vlabs.iitkgp.ac.in/mvl1/pumaIK/pumaIK_aim.html

CO-PO Mapping													
	Programme Outcomes (PO)											**PSO**	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	**3**	**2**	**2**	**-**	**3**	**-**	**-**	**-**	**-**	**-**	**1**	**3**	**-**
CO2	**3**	**3**	**2**	**2**	**3**	**-**	**-**	**-**	**-**	**-**	**1**	**3**	**1**
CO3	**3**	**3**	**-**	**2**	**3**	**-**	**-**	**-**	**-**	**-**	**1**	**2**	**1**
CO4	**3**	**3**	**-**	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**1**	**2**	**-**
The strength of mapping: 1:Low, 2:Medium, 3:High													

Assessment				
There are three components of lab assessment, LA1, LA2, and Lab ESE IMP: Lab ESE is a separate head of passing. Lab ESE is treated as End Semester Exam and is based on all experiments/lab activities.				
Assessment	**Based on**	**Conducted by**	**Typical Schedule**	**Marks**
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 6 Marks Submission at the end of Week 6	30
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 7 to Week 12 Marks Submission at the end of Week 12	30
Lab ESE	Lab Performance and documentation	Lab Course faculty	During Week 13 to Week 18 Marks Submission at the end of Week 18	40
Week 1 indicates the starting week of a semester. The actual schedule shall be as per the academic calendar. Lab activities/Lab performance shall include performing experiments, mini-projects, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.				

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AY 2026-27

Course Information

Programme	B. Tech. (Robotics and Automation)
Class, Semester	Third Year B. Tech., Sem.-VI
Course Code	1VSRA346
Course Name	Minor Project
Desired Requisites:	Mini Project -2

Teaching Scheme		**Examination Scheme (Marks)**			
Practical	12 Hrs/ Week	**LA1**	**LA2**	**Lab ESE**	**Total**
Interaction	-	30	30	40	100
		Credits: 6			

Course Objectives

1	***Identify*** and formulate relevant real-world, industrial, societal, research, or application-oriented engineering problems based on stakeholder needs and measurable requirements.
2	***Apply*** the knowledge and engineering practices acquired through the Mini Project and core Robotics and Automation courses to conceive and design integrated solutions.
3	***Develop, integrate, test, validate, and improve*** a functional prototype or proof-of-concept using appropriate engineering methods, modern tools, and quantitative evidence.
4	***Develop*** teamwork, project planning, technical documentation, and communication skills through collaborative project execution, with external or industry interaction wherever appropriate and feasible.

Course Outcomes (CO) with Bloom's Taxonomy Level

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

CO1	**Analyze** a real-world, industrial, societal, research, or application need and formulate measurable project requirements and constraints.	Analyze
CO2	**Design and develop** an integrated robotic or automation solution by applying relevant mechanical, sensing, actuation, embedded/software, and control principles.	Create
CO3	**Test, validate, and evaluate** the project/prototype against specified requirements using appropriate measurements and performance metrics, and implement justified improvements.	Evaluate
CO4	**Demonstrate** effective teamwork, project planning, individual contribution, technical documentation, and communication through reviews, report, presentation, and final demonstration.	Apply

List of Experiments / Lab Activities/ Topics

Minor Project Description:

The Minor Project is intended as a progression from the Semester V Mini Project. Students shall carry forward the practices of requirement definition, design-before-build, subsystem integration, quantitative validation, systematic debugging, and technical documentation, with greater emphasis on application context, stakeholder/user needs, engineering realization, and demonstrable utility.

A Minor Project group shall normally consist of three to four students. The project may address a new approved problem or may substantially extend earlier Mini Project work. Problems may originate from industry, society, research laboratories, faculty, student innovation, competitions, or other relevant sources. Interaction with industry, end users, research organizations, or external mentors may be undertaken wherever appropriate and feasible, while student ownership of the engineering work shall remain essential.

The project scope may include robotic or mechatronic systems, automation subsystems/cells, mobile robots, manipulators and end-effectors, machine-vision or sensing-enabled systems, embedded/control/software solutions, or other suitable Robotics and Automation applications. The expected outcome may be a functional prototype, validated proof-of-concept, integrated demonstrator, or equivalent engineering realization appropriate to the approved scope. The project shall follow a systematic engineering process including problem identification, literature/existing-solution study, requirements,

concept and feasibility assessment, system architecture, modelling/calculations and design, implementation, subsystem testing, integration, validation, iteration, and documentation. Performance shall be evaluated against defined requirements rather than only by visual demonstration.

Each team shall plan milestones and responsibilities and maintain relevant design records, resource/BOM and cost details as applicable, test data, and review evidence. Each student shall maintain an individual Project Logbook to record weekly progress, contribution, observations, and learning. The logbook shall be reviewed periodically as part of continuous assessment. At the end of the semester, each team shall submit a project report in the prescribed format and present/demonstrate the completed work during the End Semester Examination.

Textbooks	
1	W. Bolton, *"Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering"*, Pearson.
2	John J. Craig, *"Introduction to Robotics: Mechanics and Control"*, Pearson.
3	Kevin M. Lynch and Frank C. Park, *"Modern Robotics: Mechanics, Planning, and Control"*, Cambridge University Press.
4	Karl T. Ulrich, Steven D. Eppinger and Maria C. Yang, *"Product Design and Development"*, McGraw-Hill Education.
References	
1	Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani and Giuseppe Oriolo, *"Robotics: Modelling, Planning and Control"*, Springer.
2	Robert L. Norton, *"Design of Machinery"*, McGraw-Hill Education.
3	Katsuhiko Ogata, *"Modern Control Engineering"*, Pearson.
4	Jacob Fraden, *"Handbook of Modern Sensors: Physics, Designs, and Applications"*, Springer.
5	Paul Horowitz and Winfield Hill, *"The Art of Electronics"*, Cambridge University Press.
Useful Links	
1	https://ieeexplore.ieee.org
2	https://onlinecourses.nptel.ac.in
3	https://docs.ros.org
4	https://www.sciencedirect.com

CO-PO Mapping

	Programme Outcomes (PO)											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	3	1								1	2	1
CO2	3	2	3		3					1		3	3
CO3	2	2	2	3	3						2	2	2
CO4								3	3	3	1		