Savitribai Phule Pune University, Pune

Maharashtra, India

Faculty of Science and Technology

Curriculum Structure and Syllabus of

ME Production

(Robotics and Automation)

(2025 Pattern)

(With effect from Academic Year 2025-26)

Preface by Board of Studies

Dear Students and Teachers,

We, the members of Board of Studies, Production and Industrial Engineering, are very happy to present First Year Master of Robotics and Automation Engineering syllabus effective from the Academic Year 2025-26 (2025 Pattern). Robotics and Automation Engineering is a dynamic discipline that lies at the intersection of Mechanical Engineering, electronics engineering and computer science. It provides the foundation for the design, development, and application of computer systems and other computing devices. This curriculum is designed to provide students with a comprehensive understanding of the fundamental principles, theories, and practices of Robotics and Automation engineering, while also preparing them for the ever-evolving technological landscape.

The curriculum revision is mainly focused on knowledge component, skill-based activities, experiential learning and project-based activities. The revised syllabus falls in line with the objectives of NEP-2020, Savitribai Phule Pune University, AICTE New Delhi, UGC, and various accreditation agencies by keeping an eye on the technological developments, innovations, and industry requirements. Learners are now getting sufficient time for self-learning either through online courses or additional projects for enhancing their knowledge and skill sets. Learners can be advised to take up online courses, on successful completion they are required to submit certification for the same. This will definitely help learners to facilitate their enhanced learning based on their interest.

We would like to place on record our gratefulness to the faculty, students, industry experts and stakeholders for having helped us in the formulation of this syllabus.

Members of Board of Studies

Dr. K. N. Nandurkar	Co-Ordinator (BOS)
Dr S S Ohol	Member
Dr S H Wankhade	Member
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Mr Nilesh Bagul	Member

Programme Educational Objectives

Program education objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve.

PEO	PEO Focus	PEO Statements
PEO1	Core competence	To prepare globally competent post graduates with enhanced domain knowledge and skills attaining professional excellence and updated with modern technology to provide effective solutions for engineering and research problems.
PEO2	Breadth	To prepare the post graduates to work as a committed professionals with strong professional ethics and values, sense of responsibilities, understanding of legal, safety, health, societal, cultural and environmental issues.
PEO3	Professionalism	To prepare motivated post graduates with research attitude, lifelong learning, investigative approach, and multidisciplinary thinking to succeed in the career in industry/academia/research
PEO4	Team Building	To prepare post graduates with strong managerial and communication skills to work effectively as an individual as well as in teams.

Programme Outcomes (PO)

POs are statements that describe what students are expected to know and be able to do upon graduating from the program. These relate to the skills, knowledge, analytical ability, attitude and behavior that students acquire through the program. The POs essentially indicate what the students can do from subject-wise knowledge acquired by them during the program. As such, POs define the professional profile of a graduate of PG Engineering Program. NBA has defined the following three POs for a graduate of PG Engineering Program:

PO1	An ability to independently carry out research /investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

General Rules and Guidelines

1. Students may choose any one course from NPTEL/SWAYAM MOOCs courses for 3 credits as well as produce an award certificate at the end of the respective semester and One credit will be awarded by the assigned mentors through monitoring the students course progress by student for a four-week MOOCs course). Open Elective Course I and II

2. The dissertation stage I and II must result into the publication of at least two research papers (at Stage-I and Stage-II respectively) preferably in the Journal having Citation Index 2.0 and ISSN number; or paper can be published in reputed International Journal recommended by the guide of the Dissertation and the BoS supported cPGCON event for paper presentation and participation. The guides certificate covering originality of the work and plagiarism-testing result shall be included in the report along with the Published Journal Papers and cPGCON paper presentation and participation certificates. The comments received by the journal paper reviewers be attached in the Dissertation report and shall be made available during dissertation presentation/viva to the examiners.

3. Registration for NPTEL/ SWAYAM courses: Students may register for these courses during registration window as per Academic calendar for that semester.

4. Assessments consist of A) In-semester continuous assessment and B) End-semester assessment. Both shall have approximately equal weightage.

5. Skills Based Lab I & II: The laboratory work will be based on completion of assignments confined to the courses of that semester.

6. Seminar: The students shall deliver the seminar on a topic approved by authorities.

- Seminar I: Shall be on state-of-the-art topic of student's own choice approved by an authority. The student shall submit the duly certified seminar report in standard format, for satisfactory completion of the work by the concerned Guide and head of the department/institute.

- Seminar II: shall be on the topic relevant to latest trends in the field of concerned branch, preferably on the topic of specialization based on the electives selected by him/her approved by authority. The student shall submit the seminar report in standard format, duly certified for satisfactory completion of the work by the guide concerned and head of the Department/ Institute.

- Seminar III: shall preferably extension of seminar II. The student shall submit the duly certified seminar report in standard format, for satisfactory completion of the work by the concerned guide and head of the Department/ Institute.

1. **Project Work:**

The project work shall be based on the knowledge acquired by the student during the coursework and preferably it should meet and contribute towards the needs of society. The project aims to provide an opportunity of designing and building complete system or subsystems based on area where the student likes to acquire specialized skills.

- Project Work Stage – I - It is an integral part of the project work. In this, the student shall complete the partial work of the project which will consist of problem statement, literature review, project overview, scheme of implementation (Mathematical Model/SRS/UML/ERD/block diagram/ PERT chart, etc.) and Layout & Design of the Set-up. As a part of the progress report of Project work Stage-I, the candidate shall deliver a presentation on the advancement in technology pertaining to the selected dissertation topic. The student shall submit the duly certified progress report of Project work Stage-I in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

- Project Work Stage - II - The student shall complete the remaining part of the project which will consist of the fabrication of set up required for the project, workstation, conducting experiments and taking results, analysis & validation of results and conclusions. The student shall prepare the duly certified final report of project work in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

  Note: Institute must submit the list of candidates, guide and project details (title, area, problem definition, abstract - clearly indicating objectives and scope, sponsorship details, if any) to the university within month of commencement of third semester. The guide must be approved/qualified full-time teacher at the Institute. A guide can accept/enroll at most 8 students per year.

Master of Engineering Production
Robotics and Automation (2025 Pattern)

Semester I

Course Code	Course Type	Course Name	Teaching Scheme		Examination Scheme						Credits		
			Theory	Practical	CCE	EndSem	Term Work	Practical	Oral	Total	Theory	Practical	Total
PCC-501-ROA	Program core Course	Computational Mathematics	4	-	50	50	-	-	-	100	4	-	4
PCC-502- ROA	Program core Course	Robot Control System	4	-	50	50	-	-	-	100	4	-	4
PCC-503- ROA	Program core Course	Robotics Based Industrial Automation	4	-	50	50	-	-	-	100	4	-	4
PCC-504- ROA	Program core Course	Artificial Intelligence in Robotics	4		50	50	-	-	-	50	4		4
PCC-505- ROA	Program core Course	Practical I (Core subjects)		4			25		25	100		2	2
PEC-520- ROA	Program Elective Course	Elective I	3		50	50			-	-	3		3
PEC-521- ROA	Program Elective Course	Practical 2 (Core subjects)		2			25		25	100		1	1
Total			**19**	**6**	**250**	**250**	**50**		**50**	**600**	**19**	**3**	**22**

List of Elective I Courses:

PEC-520A-ROA	Mechatronics Systems and Applications
PEC-520B- ROA	Instrumentation and Sensors
PEC-520C- ROA	Flexible manufacturing systems
PEC-520D- ROA	Internet of Things

Curriculum Structure

Master of Engineering Production

Robotics and Automation (2025 Pattern)

Semester II

Course Code	Course Type	Course Name	Teaching Scheme		Examination Scheme						Credits		
			Theory	Practical	CCE	EndSem	Term Work	Practical	Oral	Total	Theory	Practical	Total
PCC-551-ROA	Major Core Course	Robot Programming	4	-	50	50	-	-	-	100	4	-	4
PCC-552- ROA	Program core Course	Advanced Robots kinematics and Dynamics	4	-	50	50	-	-	-	100	4	-	4
PCC-553- ROA	Program core Course	Robot Vision Systems	4	-	50	50	-	-	-	100	4	-	4
PCC-554- ROA	Program core Courses	Practical II (Core subjects)	-	4	-	-	50		50	100		2	2
PEC-570-ROA	Program Elective Course	Elective -II	3	-	50	50	-	-		100	3	-	3
PEC-571-ROA	Program Elective Course	Elective -III	3		-	-	50		-	50	3	-	3
SEM-580-ROA	Seminar	Technical Seminar I	-	4	-	-	25		25	50		2	2
Total			**18**	**8**	**200**	**200**	**125**		**75**	**600**	**18**	**4**	**22**

List of Elective II Courses:

PEC-570A-ROA	Service Robots
PEC-570B-ROA	Wireless Networks
PEC-570C-ROA	Signal Processing
PEC-570D-ROA	Pneumatic and Hydraulic Control

List of Elective III Courses:

PEC-571A-ROA	Simulation and Modeling
PEC-571B-ROA	MEMS and Microsystems
PEC-571C-ROA	Programming and Data Structure
PEC-571D-ROA	Mobile and Autonomous Robots

Master of Engineering Production
Robotics and Automation (2025 Pattern)
Semester III

Course Code	Course Type	Course Name	Teaching Scheme		Examination Scheme						Credits		
			Theory	Practical	CCE	EndSem	Term Work	Practical	Oral	Total	Theory	Practical	Total
RM-600-ROA	Research Methodology	Research Methodology	5	-	50	50	-	-	-	100	5	-	5
OJT-601-ROA	On Job Training/ internships	On Job Training/ internships		10			100	-	-	100		5	5
SEM-602-ROA	Seminar	Technical Seminar II		6			25	-	25	50		3	3
RPR-603-COM	Research Project	Research Project Stage-I	-	18	-	-	25		25	50		9	9
Total			5	34	50	50	150	0	50	300	5	17	22

Master of Engineering Production
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Semester IV

Course Code	Course Type	Course Name	Teaching Scheme		Examination Scheme						Credits		
			Theory	Practical	CCE	End Sem	Term Work	Practical	Oral	Total	Theory	Practical	Total
SEM-651-ROA	Seminar	Seminar on project stage II		8	-	-	50	-	50	100		4	4
RPR-652-COM	Research Project	Research Project II	-	36	-	-	150		50	200	-	18	18
		Total	**0**	**44**	**0**	**0**	**200**	**0**	**100**	**300**		**22**	**22**

*From any Discipline / Course

Savitribai Phule Pune University		
PCC-501-ROA - Computational Mathematics		
Teaching /scheme	**Credits**	**Examination Scheme**
Theory: 04Hours/Week **Practical:** 00 Hours/Week	04 00	**CCE:** 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO1: Apply matrices, Vectors for solving Linear systems
- CO2: Analyze Eigenvalues and Eigenvectors problems
- CO3. Solve examples using Inner product and dot product
- CO4: Demonstrate various PDFs with a suitable example
- CO5: Create Contingency Tables using Statistics

Unit-I: Mathematical Stochastic Processes: **(7)**

Definition and examples of SPs; Definition and examples of Markov Chains (MCs): transition probability matrix, Chapman-Kolmogorov equations; calculation of n-step transition probabilities; limiting probabilities; Classification of states; Ergodicity; Stationary Distribution, transient MC; random walk and gambler's ruin problem, applications. Kolmogorov- Feller differential equations

Unit-II: Computer based Numerical Techniques. **(7)**

Roots of non-linear equations, Solution of system of linear equations, Interpolation methods, Numerical integration, Computational Methods for Differential Equations

Unit-III: Graphs and Combinatorial Optimization:

Graphs and Digraphs: Computer representation of Graphs and Digraphs. Shortest path problems- Complexity, Bellman's Optimality Principle, Dijktra's Algorithm, Sortest Spanning Trees Kruskal's Greedy Algorithm. Networks. Flow augmenting Paths. Ford-Fulkerson Algorithm for Maximum Flow.

Unit-IV: Numerical optimization: **(7)**

Introduction to optimization: basics, classifications & characteristics, linear programming: concepts, solving method, applications. Nonlinear programming: Concepts, solving methods, examples. Dynamic programming method. Traveling salesman problem, Transportation problem

Unit-V: Multi-variable and vector calculus: **(7)**

Introduction, vector functions, multivariable derivatives, implications of multi-variable derivatives, multiple integrals, Vector fields and vector calculus

References:

1. Joseph D. Fehribach, Multivariable and Vector Calculus, Walter de Gruyter GmbH & Co KG, 2020
2. Boyce and Diprime, Elementary Differential Equations and Boundary Value Problems, Wiley, 2008
3. M. D. Raisinghania, Advanced Differential Equations, S. Chand Publications, 2008
4. Papoulis, A., Pillai, S.U., Probability, "Random Variables and Stochastic Processes", Tata McGraw-Hill, 4th Ed. 2002.
5. J. Medhi, Stochastic Processes, 3rd Edition, New Age International, 2009.
6. Jain, M. K., Iyengar, S. R. K. and Jain, R. K., "Numerical Methods for Scientific and Engineering Computation", New Age Pvt. Pub, New Delhi. 2000.
7. S Haykin, Neural Networks: A Comprehensive Foundations, Pearson,
8. S. S. Rao, Engineering Optimization: Theory and Applications, 4th Ed. Wiley, 2009.
9. Erwin Kreyszig "Advanced Engineering Mathematics"8th Edition. John Wiley & Sons

Savitribai Phule Pune University		
PCC-502-ROA – Robot Control Systems		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory: 04 Hours/Week **Practical:** 00 Hours/Week	04 00	**CCE:** 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO1. Evaluate and contrast the efficiency of polynomial time algorithms by examining their performance across the worst, best, and average case scenarios.
- CO2.Utilize appropriate algorithmic techniques to address problems involving binomial coefficients, chain matrix multiplication, and longest common subsequence.
- CO3. Develop and apply problem-solving skills to address real-world business challenges and decision-making scenarios.
- CO4.Evaluate the effectiveness and accuracy of randomized algorithms, considering both their efficiency and correctness.
- CO5.Apply problem-solving techniques tailored for multi-core, distributed, or concurrent environments to effectively address complex computational challenges.

Unit-I: Dynamics of Electromechanical Systems **(7)**

Basic Quantities: Elements and Basic Quantities in Mechanical Systems, Elements and Basic Quantities in Electric Systems, Fundamental Concepts of Mechanical Systems, The Principle of Least Action, Dynamics, Non-potential and Dissipative Forces, Equations of Motion, Properties of Equations of Motion, Operational Space Dynamics, Electric and Electromechanical Systems, Electrical Systems, Electromechanical Systems, Electrical Machines

Unit -II Control System Design **(7)**

Basic Concepts Basic Forms in Control Systems, Basic Relations, Stability, Sensitivity Function, External Inputs, State Space Representation: State Feedback, Stability, Observers, Systems with Observers, Disturbance Estimation, Dynamic Systems with Finite Time Convergence: Equivalent Control and Equations of Motion, Existence and Stability, Design, Control in Linear Systems, Sliding Mode Based Observers, acceleration control

Unit -III Disturbance Observers (7)

Disturbance Model Based Observers, Velocity Based Disturbance Observer, Position Based Disturbance Observer, Closed Loop Disturbance Observers, Internal and External Forces Observers, Observer for Plant with Actuator Plant with Neglected Dynamics of Current Control Loop, Plant with Dynamics in Current Control Loop,

Estimation of Equivalent Force and Equivalent Acceleration, Functional Observers, Dynamics of Plant with Disturbance Observer, Disturbance Estimation Error, Dynamics of Plant With Disturbance Observer, Properties of Measurement Noise Rejection, Control of Compensated Plant

Unit-IV Interactions and Constraints **(7)**

Interaction Force Control: Proportional Controller and Velocity Feedback, Environment with Losses, Lossless Environment, Control of Push Pull Force, Constrained Motion Control, Modification of Reference, Modification by Acting on Equivalent Acceleration, Motion Modification while Keeping Desired, Force Profile, Impedance Control, Force Driven Systems, Position and Force Control in Acceleration, Dimension, Interactions in Functionally Related Systems, Grasp Force Control , Functionally Related Systems.

Unit-V Bilateral Control Systems (7)

Bilateral Control without Scaling, Bilateral Control Design, Control in Systems with Scaling in Position and Force, Bilateral Control Systems in Acceleration Dimension, Bilateral Systems with Communication Delay, Delay in Measurement Channel, Delay in Measurement and Control Channels, Closed Loop Behavior of System with Observer, Bilateral Control in Systems with Communication Delay

References:

1.R Kelly, D. Santibanez, LP Victor and Julio Antonio, "Control of Robot Manipulators in Joint Space", Springer, 2005.

2. A Sabanovic and K Ohnishi, "Motion Control Systems", John Wiley & Sons (Asia), 2011.

3. R M Murray, Z. Li and SS Sastry, "A Mathematical Introduction to Robotic Manipulation", CRC Press, 1994.

4. J J Craig, "Introduction to Robotics: Mechanics and Control", Prentice Hall, 2004.

5. J J E Slotine and W Li, "Applied Nonlinear Control", Prentice Hall, 1991.

6. Sebastian Thrun, Wolfram Burgard, Dieter Fox, "Probabilistic Robotics", MIT Press, 2005.

7. Carlos, Bruno, Georges Bastin, "Theory of Robot Control", Springer, 2012

Savitribai Phule Pune University		
PCC-503-ROA – Robotics Based Industrial Automation		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week **Practical:** 00 Hours/Week	04 00	**CCE:** 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO1: Apply different feature extraction, classification, regression, algorithms and modeling.
- CO2: Evaluate the performance of an algorithm and comparison of different learning techniques.
- CO3: Understand unsupervised methods and their applications
- CO4: Optimize the algorithms effectively
- CO5: Apply techniques using different case studies

Unit- I: Introduction **(8)**

Definition, automation principles and strategies, scope of automation, socio-economic consideration, low cost automation, basic elements of advanced functions, Information processing in manufacturing industry, Production concepts and automation strategies.
Fixed Automation: Automated Flow lines, Methods of Work part Transport, Transfer Mechanism - Continuous transfer, intermittent transfer, Indexing mechanism, Operator-Paced Free Transfer Machine, Buffer Storage, Control Functions, Automation for Machining Operations, Design and Fabrication Considerations.
Modeling Automated Manufacturing Systems: Role of Performance Modeling, Performance Measures, Performance Modelling Tools: Simulation Models, Analytical Models.

Unit –II: Motion Analysis **(8)**

Trajectories, Smooth One-Dimensional Trajectories, Multi-Dimensional Case, Multi-Segment Trajectories, Interpolation of Orientation in 3D, Cartesian Motion, Time Varying Coordinate Frames, Rotating Coordinate Frame, Incremental Motion, Inertial Navigation Systems. Mobile Robot Vehicles, Mobility, Car-like Mobile Robots, Moving to a Point, Following a Line, Following a Path, Moving to a Pose.

Unit –III: Robot Arm Kinematics **(8)**
Describing a Robot Arm, Forward Kinematics, A 2-Link Robot, A 6- Axis Robot, Inverse Kinematics, Closed-Form Solution, Numerical Solution, Under-Actuated Manipulator, Redundant Manipulator, Trajectories, Joint-Space Motion, Cartesian Motion, Motion through a Singularity

Unit- IV: ROS for Industrial Application: (8)

Installing ROS, Understanding the ROS Filesystem level, Packages, Stacks, Messages, Services, Understanding the ROS Computation Graph level, Nodes, Topics, Services, Messages, Bags, Master, Parameter Server, Creating workspace, Creating & Building an ROS package, Creating & Building the node, Visualization of images, Working with stereo vision, 3D visualization, Visualizing data on a 3D world using rviz

Unit –V: Robot Programming for Industrial applications: (8)

Using Sensors and Actuators with ROS, articulated robot structure, joint movements, work envelop, motors, encoders, micro switch, transmission, gripper, articulated robot programming, Mobile Robot Programming, Industrial Robot Programming. Programming robots for Fanuc, Mitsubishi, Kuka, ABB robots

References:

1. M.P. Groover "Automation, Production Systems and Computer Integrated Manufacturing", Pearson Education.
2. Krishna Kant,"Computer Based Industrial Control" -, EEE-PHI
3. Webb John Principles and Applications of PLC -, McMillan 1992
4. Tiess Chiu Chang & Richard A. Wysk "An Introduction to Automated Process Planning Systems"
5. Amber G.H & P.S. Amber "Anatomy of Automation", Prentice Hall.
6. Peter Corke Robotics, Vision and Control: Fundamental Algorithms in MATLAB® -, Springer Tracts in Advanced Robotics, Volume 73, 2011 2.
7. Aaron Martinez & Enrique Fernández ,Learning ROS for Robotics Programming, Packt Publishing
8. Yoram Koren , Robotics for Engineers -, McGraw Hill International, 1st edition, 1985.
9. M. Weiss, R. N. Nagel, M. P. Groover, Industrial Robotics , McGraw Hill International, 2nd edition, 2012.
10. Fu, Lee and Gonzalez. Robotics, control vision and intelligence- McGraw Hill International, 2nd edition, 2007.
11. John J. Craig, Introduction to Robotics-, Addison Wesley Publishing, 3rd edition, 2010.

Savitribai Phule Pune University		
PCC-504-ROA – Artificial Intelligence in Robotics		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week **Practical:** 00 Hours/Week	04 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Course Outcomes: Upon successful completion of this course, students will be able to:

- CO1: Apply different feature extraction, classification, regression, algorithms and modeling.
- CO2: Evaluate the performance of an algorithm and comparison of different learning techniques.
- CO3: Understand unsupervised methods and their applications
- CO4: Optimize the algorithms effectively
- CO5: Apply techniques using different case studies

Unit -I: Scope of AI and Problem solving **(8)**

Introduction to Artificial Intelligence-Introduction, Intelligent agents, problem solving by search, Adversarial search The planning problem, planning with state-space search, partial-order planning, planning graph, planning with propositional logics. Planning & acting in the real world.

Unit -II: Knowledge Representation& Learning **(8)**

Uncertainty, probabilistic reasoning-Bayesian Network, probabilistic reasoning over time-Inference in temporal Model, Hidden Markov models-Kalman filters, Dynamic Bayesian Network, speech recognition.
Learning: Concept of learning, learning automation, genetic algorithm, learning by inductions, neural nets.
Programming Language: Introduction to programming Language. Handling Uncertainties: Non-monotonic reasoning, Probabilistic reasoning, use of certainty factors, Fuzzy logic

Unit -III: Expert system **(8)**

Expert system - Introduction, difference between expert system and conventional programs, basic activities of expert system – Interpretation, Prediction, Diagnosis, Design, Planning, Monitoring, Debugging, Repair, Instruction, Control. Basic aspects of expert system -Acquisition Unit, Knowledge base - Production rules, semantic net, frames. Inference engine - Backward chaining and forward chaining. Explanatory interface.

Unit -IV: Communication & Perception **(8)**

Communication, Probabilistic language processing-probabilistic-language models-information retrieval-extraction-machine translation, perception-image formation- image processing operations-object recognition

Unit -VI: AI in Robotics: **(8)**

Robotic perception, localization, mapping- configuring space, planning uncertain movements, dynamics and control of movement, Ethics and risks of artificial intelligence in robotics. Case study of AI in robotics.

References:

1. Stuart Russell, Peter Norvig, Artificial Intelligence: A modern approach, Pearson Education, India.
2. Negnevitsky, M, Artificial Intelligence: A guide to Intelligent Systems,. Harlow: Addison-Wesley, 2002.
3. E. Rich and K. Knight, “Artificial intelligence”, TMH, 2nd ed..
4. Nilsson, N. J. (1986). Principles of artificial intelligence. Morgan Kaufmann.
5. Craig, J. J. (2009). Introduction to robotics: mechanics and control, 3/E. Pearson Education India.
6. D.W. Patterson, “Introduction to AI and Expert Systems”, PHI, 1992.
7. Peter Jackson, “Introduction to Expert Systems”, AWP, M.A., 1992.
8. R.J. Schalkoff, “Artificial Intelligence - an Engineering Approach”, McGraw Hill Int. Ed., Singapore, 1992.
9. M. Sasikumar, S. Ramani, “Rule Based Expert Systems”, Narosa Publishing House, 1994.

Savitribai Phule Pune University		
PCC-505- ROA - Skill Based Laboratory - I		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 00 Hours/Week **Practical:** 04 Hours/Week	00 02	Term Work : 25 Marks **Oral** : 25 Marks

List of Practical

1. Industrial case study on design of experiment
2. Industrial case study on multi-attribute decision making
3. Numerical solution of a partial differential equation by using different methods
4. Manufacturing application of T test and Chi-square test.
5. Microcontroller lab - programming (free software /open source)
6. Integration of assorted sensors (IR, Potentiometer, strain gages etc.),
7. Micro controllers and ROS (Robot Operating System) in a robotic system. (Free software or, Matlab)
8. Control experiment using available hardware or software. (Open source or Matlab).

Savitribai Phule Pune University		
PEC-520A- ROA - Mechatronics Systems and Applications		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit –I: Sensors and Transducers **(8)**

Introduction - Performance Terminology - Displacement, Position and Proximity -Velocity and Motion -Fluid pressure - Temperature sensors - Light sensors - Selection of sensors - Signal processing - Servo systems.

Unit –II: Microcontrollers **(8)**

Introduction - Architecture - Pin configuration - Instruction set - Programming of Microprocessors using 8085 instructions - Interfacing input and output devices - Interfacing D/A converters and A/D converters -Applications - Temperature control - Stepper motor control - Traffic light controller.

Unit –III: Input output Systems **(8)**

Interfacing requirements, interface adapters, buffers, Tri-state buffers, hand shaking and Serial interfacing. Parallel interfacing, Function of synchronous communication, Networks.

Unit –IV: Programmable Logical Controllers **(8)**

Basic structure of PLC, program of PLC, logic functions, latching and sequencing, Develop programs involving timers, internal relays, counters, shift registers, PLC Programming.

Unit –V: Mechatronics Systems & Applications **(8)**

Case studies of Mechatronic systems designs, like piece counting system, Pick and place manipulator, Simple assembly task involving a few parts, Part loading / unloading system, Automatic tool and pallet changers etc. Fault finding and troubleshooting.

References:

1. Bolton, “Mechatronics: Electronic Control System in Mechanical and Electrical Engineering”, Pearson Education Ltd. ISBN:8131732533
2. B. H. Histard, D. G. Alciator, “Introduction to Mechatronics and Measurement Systems”, Tata McGraw Hill Publication, ISBN 0-07-052970-8.
3. B. C. Kuo, “Automatic Control Systems”, prentice Hall, ISBN 0-87-692480-1.
4. Programmable Logical Controller”, Hackworth, Pearson Education, (2008)
5. C. D. Johnson, “Process Control Instrumentation Technology”, Prentice Hall of India Pvt. Ltd., New Delhi.
6. D. Shetty, R. Kolk, “Mechatronics System Design”, Thomson Books Pub., ISBN98-1240062-2.
7. AppuKuttam “Mechatronics”, Oxford Publications, 1st Edition.
8. Gary Dunning, “Programmable Logical Controller”, Cengage Learning, 3rd Edition.

Savitribai Phule Pune University		
PEC-520B- ROA - Instrumentation & Sensors		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit -I : Sensor Based Measurement Systems (8)

General Concepts And Terminology, Sensor Classification, General Input-Output Configuration, Static Characteristics Of Measurement Systems, Dynamic Characteristics, Other Sensor Characteristics, Primary Sensors, Materials For Sensors, Microsensors Technology.

Unit- II : Displacement, Force, Pressure Sensors. (8)

Measurement of displacement using Potentiometer, LVDT & Optical Encoder, Measurement of force using strain gauge, Measurement of pressure using LVDT based diaphragm & piezoelectric sensor.

Unit- III: Temperature, Position, Proximity, Flow and Level Sensors. (8)

Measurement of temperature using Thermistor, Thermocouple & RTD, Concept of thermal imaging, Measurement of position using Hall effect sensors, Proximity sensors: Inductive & Capacitive, Use of proximity sensor as accelerometer and vibration sensor, Flow Sensors: Ultrasonic & Laser, Level Sensors: Ultrasonic & Capacitive.

Unit -IV: DAQ Methods (8)

Data Acquisition Methods: Basic block diagram, Analog and Digital IO, Counters, Timers, Types of ADC: successive approximation and sigma-delta, Types of DAC: Weighted Resistor and R-2R Ladder type, Use of Data Sockets for Networked Communication.

Unit -V: Intelligent Sensors (8)

Intelligent Sensors: General Structure of smart sensors & its components, Characteristic of smart sensors: Self calibration, Self-testing & self-communicating, Application of smart sensors: Automatic robot control & automobile engine control.

References:

1. D. Patranabis, “Principle of Industrial Instrumentation”, Tata McGraw Hill
2. DVS Murthy, Transducers and Instrumentation, PHI 2nd Edition 2013
3. S. Gupta, J.P. Gupta / PC interfacing for Data Acquisition & Process Control, 2nd ED / Instrument Society of America, 1994.
4. Gary Johnson / Lab VIEW Graphical Programing II Edition / McGraw Hill 1997
5. Bolton, “Mechatronics: Electronic Control System in Mechanical and Electrical Engineering”, Pearson Education Ltd. ISBN:8131732533
6 D. Shetty, R. Kolk, “Mechatronics System Design”, Thomson Books Pub., ISBN98-1240062-2.
9. E.O. Doebelin, “Measurement Systems”, McGraw Hill.
10. Arun K. Ghosh, Introduction to measurements and Instrumentation, PHI, 4th Edition 2012
11. A.D. Helfrick and W.D. Cooper, Modern Electronic Instrumentation & Measurement Techniques, PHI - 2001

Savitribai Phule Pune University		
PEC-520C- ROA - Flexible Manufacturing Systems		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00Hours/Week	03 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit -I: Introduction **(8)**

Introduction to manufacturing system, different type of manufacturing system, volume variety relationship for understanding manufacturing system.

Flexible Manufacturing System: Components of an FMS, types of system, where to apply FMS technology, FMS work stations. Material handling and storage system: Functions of the handling system, FMS layout configuration, Material handling equipment.

Unit- II : Distributed data processing in FMS **(8)**

DBMS and their applications in CAD/CAM and FMS distributed systems in FMS -Integration of CAD and CAM - Part programming in FMS, tool data base - Clamping devices and fixtures data base.

Unit- III: Group Technology **(8)**

Cellular Manufacturing-Part families, part classification and coding. Types of classification and coding system, Machine cell design: The composite part concept, types of cell design. Virtual Cell Manufacturing System.

Just In Time and Lean Production: Lean Production and Waste in manufacturing, just in time production system, automation, work involvement.

Unit -IV: Production Planning and control systems **(8)**

Aggregate Production Planning and the master production schedule, Material Requirements and Planning, capacity planning, shop floor control, inventory control, extensions of MRP

Computer Aided Process Planning: Generative and variant types, backward and forward approach, feature based and CAD based CAPP.

UNIT-V : FMS-Support Systems **(8)**

Contact and non-contact inspection principles - programming and operation-in cycle gauging. Part programming in FMS, tool data base - Clamping devices and fixtures data base. Material Handling systemsin FMS: Conveyors - AGVs - industrial robots in material handling - AS/RS. Interfacing of computers, machine tool controllers and handling systems: communications standards Programmable Logic Controllers (PLC's) – Interfacing, Computer aided Project planning- dynamic part scheduling.

References:

1. Paul Ranky., "The design and operation of FMS", IFS publication
2. Mikell P Groover, "Automation Production systems, Computer Integrated Manufacturing", Prentice Hall
3. David J. Parrish, "Flexible Manufacturing" Butterworth-Heinemann, 1990
4. Computer Aided Manufacture by Chien Chang and Richard A Wysk, Prentice HALL
5. P. Radhakrishnan, S. Subramanyan, "CAD / CAM / CIM", New Age International.
6. William W Luggen, "Flexible Manufacturing Cells and System" Prentice Hall of Inc New Jersey, 1991
7. Reza A Maleki "Flexible Manufacturing system" Prentice Hall of Inc New Jersey, 1991
8. John E Lenz "Flexible Manufacturing" Marcel Dekker Inc New York ,1989.

Savitribai Phule Pune University		
PEC-520D- ROA - Internet of Things		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit I - Introduction & Basic of IoT **(8)**

Definition, Characteristics, Physical and Logical Designs, challenges, Technological trends in IOT, IoT Examples, M2M

UNIT- II: Components, Communication and Networking **(8)**

Introduction to Sensing and Networking: Sensing & actuation, Wireless Senor network, Senor nodes, Communication Protocols, M2M Communication, Networking Hardware, Networking Protocols

UNIT –III: IoT System Management **(8)**

Network Operator Requirements, IoT Platform Design Specification - Requirements, Process, Do- main Model, Service, IoT Level, Function, Operational view, Device and Component Integration, Application development.

UNIT –IV: Networking and Computing **(8)**

File Handling, Python Packages for IoT, IoT Physical Servers - Cloud Storage Models, Communication APIs

UNIT- V: IoT Clouds and Data Analytics and Applications **(8)**

RESTful Web API, Amazon Web Services for IoT, Apache Hadoop, Batch Data Analysis, Chef, Chef Case Studies, Puppet, NETCONF-YANG. Case studies: smart cities, smart home, connected vehicles, Industrial IOT.

References:

1. Kamal, R., "Internet of Things - Architecture and Design Principles," 1st Edition, Mcgraw Hill,2017.
2. Simone Cirani," Internet of Things- Architectures, Protocols and Standards", WILEY,2018.
3. Alessandro Bassi," Enabling Things to Talk- Designing IoT solutions with the IoT Architectural Reference Model", Springer,2013
4. D. Patranabis, "Sensor & Transducers", Murthy Prentice Hall India Learning Private Limited, 2nd edition, 2009.
5. Jacob Fraden," Handbook of Modern Sensors", Physics, Designs, and Applications, Fifth Edition, Spinger,2016

Savitribai Phule Pune University Second Year of Artificial Intelligence and Data Science (2024 Course)		
PEC-521- ROA - Skill Based Laboratory - II		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 00 Hours/Week **Practical:** 02 Hours/Week	00 01	Term Work : 25 Marks **Oral**: 25 Marks

List of Practical

1. Mechatronics system modeling and simulation (Matlab/ Labview),
2. Integration of sensors, actuators and controllers
3. PLC and SCADA
4. Embedded systems and microcontrollers - Arduino, PIC, Raspberry Pi, Interfacing
5. IOT and smart systems lab
6. Virtual sensors and automation

Savitribai Phule Pune University		
PCC-551-ROA - Robot Programming		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week **Practical:** 00 Hours/Week	04 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit -I : Basics of Robot Programming **(10)**

Robot programming-Introduction-Types- Flex Pendant- Lead through programming, Coordinate systems of Robot, Robot controller- major components, functions-Wrist Mechanism-Interpolation-Interlock commands-Operating mode of robot, Jogging Types, Robot specifications- Motion commands, end effectors and sensors commands

Unit- II : VAL Language/Melfa language **(9)**

Robot Languages-Classifications, Structures- VAL language commands- motion control, hand control, program control, pick and place applications, palletizing applications using VAL, Robot welding application using VAL program-WAIT, SIGNAL and DELAY command for communications using simple applications, MELFA language basic commands- Motion Instructions-Pick and place operation using Industrial robot- manual mode, automatic mode, subroutine command based programming

UNIT- III: RAPID Language **(9)**

RAPID language basic commands- Motion Instructions-Pick and place operation using Industrial robot- manual mode, automatic mode, subroutine command based programming. Movemaster command language-Introduction, syntax, simple problems, R

UNIT -IV: Practical Study of Virtual Robot **(9)**

Robot cycle time analysis-Multiple robot and machine Interference-Process chart Simple problems-Virtual robotics, Robot studio online software-Introduction, Jogging, components, work planning, program modules, input and output signals-Singularities Collision detection-Repeatability measurement of robot-Robot economics. VAL-II programming-basic commands, applications- Simple problem using conditional statements-Simple pick and place applications-Production rate calculations using robot. AML Language-General description, elements and functions, Statements, constants and variables-Program control statements- Operating systems, Motion, Sensor commands-Data processing.

UNIT –V: Robot Programming Applications **(9)**

Robot programming synthesis, robot programming for foundry, press work and heat treatment, welding, machine tools, material handling, warehousing assembly, etc., automatic storage and retrieval system, Robot economics and safety, Robot integration with CAD/CAM/CIM, Collision free motion planning.

References:

1. Deb. S. R. “Robotics Technology and Flexible Automation”, Tata McGraw Hill publishing company limited.
2. Mikell. P. Groover, “Industrial Robotics Technology”, Programming and Applications, McGraw Hill Co, 1995.
3. Klafter. R.D, Chmielewski.T.A and Noggin’s, “Robot Engineering: An Integrated Approach”, Prentice Hall of India Pvt. Ltd.,1994.
4. Fu .K. S, Gonzalez .R. C. & Lee .C.S.G, “Robotics Control, Sensing, Vision and Intelligence”, McGraw Hill Book co, 1987.
5. Craig .J. J, “Introduction to Robotics Mechanics and Control”, Addison- Wesley, 1999.
6. Robotics Lab manual, 2007.

Savitribai Phule Pune University		
PCC-552- ROA - Advanced Robot Kinematics and Dynamics		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week **Practical:** 00 Hours/Week	04 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit I: Elements of robots – links, joints, actuators, and sensors **(7)**

Position and orientation of a rigid body, Homogeneous transformations, Representation of joints, link representation using D-H parameters, Examples of D-H parameters and link transforms, different kinds of actuators – stepper, DC servo and brushless motors, model of a DC servo motor, Types of transmissions, Purpose of sensors, internal and external sensors, common sensors - encoders, tachometers, strain gauge based force-torque sensors, proximity and distance measuring sensors, and vision.

Unit II: Kinematics of serial robots **(7)**

Introduction, Direct and inverse kinematics problems, Examples of kinematics of common serial manipulators, workspace of a serial robot, Inverse kinematics of constrained and redundant robots, Tractrix based approach for fixed and free robots and multi-body systems, simulations and experiments, Solution procedures using theory of elimination, Inverse kinematics solution for the general 6R serial manipulator.

Unit III: Kinematics of parallel robots **(7)**

Degrees-of- freedom of parallel mechanisms and manipulators, Active and passive joints, Constraint and loop-closure equations, Direct kinematics problem, Mobility of parallel manipulators, Closed-from and numerical solution, Inverse kinematics of parallel manipulators and mechanisms, Direct kinematics of Gough-Stewart platform.

Unit IV: Velocity and static analysis of robot manipulators **(7)**

Linear and angular velocity of links, Velocity propagation, Manipulator Jacobians for serial and parallel manipulators, Velocity ellipse and ellipsoids, Singularity analysis for serial and parallel manipulators, Loss and gain of degree of freedom, Statics of serial and parallel manipulators, Statics and force transformation matrix of a Gough-Stewart platform, Singularity analysis and statics.

UNIT V: Dynamics of serial and parallel manipulators **(7)**

Mass and inertia of links, Lagrangian formulation for equations of motion for serial and parallel manipulators, Generation of symbolic equations of motion using a computer, Simulation (direct and inverse) of dynamic equations of motion, Examples of a planar 2R and four-bar mechanism, Recursive dynamics, Commercially available multibody simulation software (ADAMS) and Computer algebra software Maple.

References:

1. Ghosal,A., Robotics: Fundamental Concepts and Analysis, Oxford University Press, 2nd reprint, 2008.
2. K. S. Fu, R. C. Gonzalez and C. S. G. Lee, "Robotics: Control, Sensing, Vision, and Intelligence," McGraw-Hill Inc., Boston

3. Mark Spong, M. Vidyasagar: Robot Dynamics & Control (Wiley)
4. Hartenberg and Denavit, : Kinematics and Synthesis of Linkages", McGraw Hill Book Co
5. Herman Bruyninckx, : Robot Kinematics and Dynamics,

Savitribai Phule Pune University		
PCC-553- ROA - Robot Vision System		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04 Hours/Week **Practical:** 00Hours/Week	04 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit -I: Vision System: **(8)**

Camera Geometry and Color Sensing, Basic Components - Elements of visual perception: structure of human eye, image formation in the eye - pinhole cameras - colour cameras - image formation model - imaging components and illumination techniques - picture coding - basic relationship between pixels - Camera-Computer interfaces, Image capture and digitization

Unit -II: Low Level Vision Algorithms: **(8)**

Sources of imagery, physics of imaging, Representing, acquiring, and displaying images, Grayscale, color, noise, lens distortion, and filtering. Image representation – image transformation & calibration, gray level transformations, Histogram equalization, image subtraction, image averaging - Filters: smoothing spatial filters, sharpening spatial filters, smoothing frequency domain filters, sharpening frequency domain filters - edge detection, image Convolution,

Unit -III: High Level Vision Algorithms: **(8)**

Image Segmentation (based on discontinuity and similarity), Edge linking and boundary detection, thresholding, Region-oriented segmentation, the use of motion - Description: Boundary Descriptors, Regional Descriptors, Recognition: Decision-Theoretic methods, structural methods. Enhancing features and correcting imperfections, addressing noise, lens distortion, and blurring, Image Morphing, Image Blending, Image Carving, Image transforms; digital Fourier transform, fast Fourier transform, other transforms, correlation; image enhancement; image restoration; Geometric transformation; image compression; error free and lossy compression; edge detection; hough transform, region based segmentation; image feature/region representation and descriptors.

Unit -IV: Object Recognition: **(8)**

Object recognition, Approaches to Object Recognition, Recognition by combination of views - objects with sharp edges, using two views only, using a single view, use of dept values, SVM and Object Recognition

Unit -V: Applications: **(8)**

Camera Calibration - Stereo Imaging - Transforming sensor reading, Mapping Sonar Data, Aligning laser scan measurements - Vision and Tracking: Following the road, Iconic image processing, Multiscale image processing, Video Tracking - Learning landmarks: Landmark spatiograms, K-means Clustering, EM Clustering, Kalman Filtering.

References:

1. Horn, Berthold K. P. *Robot Vision*. Cambridge, MA: MIT Press /McGraw-Hill, March 1986. ISBN: 0262081598.
2. Damian m Lyons, “Cluster Computing for Robotics and Computer Vision”, World Scientific, Singapore, 2011.
3. Carsten Steger, Markus Ulrich, Christian Wiedemann, “Machine Vision Algorithms and Applications”, WILEY-VCH, Weinheim, 2008.

4. Rafael C. Gonzalez and Richard E. Woods, “Digital Image Processing”, Addition - Wesley Publishing Company, New Delhi, 2007.
5. Shimon Ullman, “High-Level Vision: Object recognition and Visual Cognition”, A Bradford Book, USA, 2000.
6. R.Patrick Goebel, “ ROS by Example: A Do-It-Yourself Guide to Robot Operating System - Volume I”, A Pi Robot Production, 2012.
7. Bernd Jahne, “Digital Image Processing”, Springer Publication, 2013.

Savitribai Phule Pune University Second Year of Artificial Intelligence and Data Science (2024 Course)		
PCC-554- ROA - Skill Based Laboratory - II		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 00 Hours/Week **Practical:** 04 Hours/Week	00 02	Term Work : 50 Marks **Oral**: 50 Marks

List of Practical

1. Forward and inverse kinematics validation on robot
2. Writing programs for pick and place operations, Continuous path for ABB/Kuka/Fanuc Robots. Obstacle avoidance path planning
3. Programming grippers (pneumatic/electric), Force/torque sensor integration, Writing programs for assembly operations
4. Programming pray painting / welding simulation programs
5. Material handling with conveyor synchronization
6. Programming for robotic welding
7. Programming for robotic assembly
8. Programming for CNC machine tending

Savitribai Phule Pune University		
PEC-570A-ROA - Service Robots		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit -I: Introduction **(8)**

History of service robotics - Present status and future trends - Need for service robots - Applications- Examples and Specifications of service and field Robots. Non-conventional Industrial robots the humanoid robots functions & its operations.

Unit- II: Localization **(8)**

Introduction-Challenges of Localization- Map Representation- Probabilistic Map based Localization- Monte carlo localization- Landmark based navigation-Globally unique localization- Positioning beacon systems- Route based localization.

Unit- III: Planning and Navigation **(8)**

Introduction-Path planning overview- Road map path planning- Cell decomposition path planning-Potential field path planning-Obstacle avoidance - Case studies: Tiered robot architectures.

Unit- IV: Field Robots **(8)**

Ariel robots- Collision Avoidance-Robots for agriculture, mining, exploration, underwater, Civilian and military applications, Nuclear applications, Space applications.

Unit- V: Humanoids **(8)**

Wheeled and legged, Legged locomotion and balance, Arm movement, Gaze and auditory orientation control, Facial expression, Hands and manipulation, Sound and speech generation, Motion capture/Learning from demonstration, Human activity recognition using vision, touch, sound, Vision, Tactile Sensing, Models of emotion and motivation. Performance, Interaction, Safety and robustness, Applications- Case studies.

Unit - VI: Domestic and Medical Robotics **(8)**

Introduction to home automation, domestic robotics, cleaning robots, lawn moving robots, challenges and applications. Introduction to medical robotics, historical background, surgical robots, rehabilitation robots, exoskeletons, issues related to safety and ethics, applications and challenges in medical robotics.

References:

1. Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza, „Introduction to Autonomous Mobile Robots‖, Bradford Company Scituate, USA, 2004
2. Riadh Ziaer (Ed) „The future of Humanoid Robots- Research and applications‟, Intech Publications, 2012.
3. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "Robotics Engineering - An Integrated Approach", Eastern Economy Edition, Prentice Hall of India P Ltd., 2006.
4. Kelly, Alonzo; Iagnemma, Karl; Howard, Andrew, "Field and Service Robotics ", Springer, 2011
5. Groover M. P., “Industrial Robotics: Technology, Programming and Applications, Tata McGraw Hill Publication
6. Taghirad H.D, “Parallel Robots: Mechanics and Control”, CRC Press.

7. Moore S. W., Bohm H., and ,Jensen V., “Underwater Robotics: Science, Design & Fabrication”, Marine Advanced Technology Education (MATE) Center, 2010
8. Mejia O. D. M., Gomez J. A. E., (eds.), “Aerial Robots: Aerodynamics, Control and Application” InTech Open Publications.
9. Bock T., Linner T., “Robot Oriented Design: Design and Management Tools for the Deployment of Automation and Robotics in Construction”, Cambridge University Press,
10. Robotics and Mechatronics for Agriculture, by Zhang D., Wei B., (eds.), CRC Press.
11. Medical Robotics, by Schweikard A., Ernst F., Springer Publications
12. Household Service Robotics, by Xu Y., Qian H., and Wu X., Zhejiang University Press.
13. Springer Handbook of Robotics, by Khatib O., (ed.), Springer Publications.
14. Humanoid Robotics: A Reference, Vadakkepat P., Goswami, A, Springer Netherlands, 2017.
15. On Road Intelligent Vehicles, by Kala R., Elsevier Publications, 2017

Savitribai Phule Pune University		
PEC-570B-ROB - Wireless Networks		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit- I : Wireless LAN **(8)**

Introduction-WLAN technologies: Infrared, UHF narrowband, spread spectrum -IEEE802.11: System architecture, protocol architecture, physical layer, MAC layer, 802.11b, 802.11a - Hiper LAN: WATM, BRAN, HiperLAN2 - Bluetooth: Architecture, Radio Layer, Baseband layer, Link manager Protocol, security - IEEE802.16-WIMAX: Physical layer, MAC, Spectrum allocation for WIMAX

Unit- II : Mobile Network Layer **(8)**

Introduction - Mobile IP: IP packet delivery, Agent discovery, tunnelling and encapsulation, IPV6-Network layer in the internet- Mobile IP session initiation protocol - mobile ad-hoc network: Routing, Destination Sequence distance vector, Dynamic source routing.

Unit- III: Mobile Transport Layer **(8)**

TCP enhancements for wireless protocols - Traditional TCP: Congestion control, fast retransmit/fast recovery, Implications of mobility - Classical TCP improvements: Indirect TCP, Snooping TCP, Mobile TCP, Time out freezing, Selective retransmission, Transaction oriented TCP - TCP over 3G wireless networks.

Unit- IV: Wireless Wide Area Network **(8)**

Overview of UTMS Terrestrial Radio access network-UMTS Core network Architecture: 3G-MSC, 3G-SGSN, 3G-GGSN, SMS-GMSC/SMS-IWMSC, Firewall, DNS/DHCP-High speed Downlink packet access (HSDPA)- LTE network architecture and protocol.

Unit- V: 4G Networks **(8)**

Introduction - 4G vision - 4G features and challenges - Applications of 4G - 4G Technologies: Multicarrier Modulation, Smart antenna techniques, OFDM-MIMO systems, Adaptive Modulation and coding with time slot scheduler, Cognitive Radio.

Unit- VI: 5G Networks **(8)**

5G Architecture: Software Defined Networking – Network Function Virtualization – Basics about RAN Architecture -High-Level Requirements for 5G Architecture - Functional Architecture and 5G Flexibility - Physical Architecture and 5G Deployment Millimeter Wave Communication: Channel Propagation - Hardware Technologies for mmWave Systems - Deployment Scenarios - Architecture and Mobility - Beamforming - Physical layer Techniques

References:

1. Next Generation Wireless LANs by EldadPerahia, Robert Stacey
2. Wireless Networks by Clint Smith and Daniel Collins
3. 802.11 Wireless Networks: The Definitive Guide, Second Edition

4. Designing and Deploying 802.11ac Wireless Networks by Jim Geier
5. Jochen Schiller, "Mobile Communications", Second Edition, Pearson Education 2012.(Unit I,II,III)
6. Vijay Garg , "Wireless Communications and networking", First Edition, Elsevier 2007.
7. Wireless Networking Absolute Beginner's Guide by Michael Miller
8. Computer Networking First-Step by Norman Laurence
9. Networking Made Easy by James Bernstein
10. WiFi Analytics by Luke Buikema and John Kerbers
11. Wireless Communication Networks and Systems, by Cory Beard and William Stallings

Savitribai Phule Pune University		
PEC-570C-ROB - Signal Processing		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit- I: Introduction to Signals & Systems Signal Processing (8)

Signals: Introduction, Graphical, Functional, Tabular and Sequence representation of Continuous and Discrete time signals. Basics of Elementary signals: Unit step, Unit ramp, Unit parabolic, Impulse, Sinusoidal, Real exponential, Complex exponential, Rectangular pulse, Triangular, Signum, Sinc and Gaussian function.
Operations on signals: time shifting, time reversal, time scaling, amplitude scaling, signal addition, subtraction, signal multiplication. Communication, control system and Signal processing examples.
Classification of signals: Deterministic, Random, periodic , Non periodic, Energy , Power, Causal , Non-Causal, Even and odd signal.
Systems: Introduction, Classification of Systems: Lumped Parameter and Distributed Parameter System, static and dynamic systems, causal and non-causal systems, Linear and Non- linear systems, time variant and time invariant systems, stable and unstable systems, invertible and non- invertible systems.

Unit- II: Time domain representation of LTI System (8)

Input-output relation, definition of impulse response, convolution sum, convolution integral, computation of convolution integral using graphical method for Unit step to Unit step, Unit step to exponential, exponential to exponential, Unit step to rectangular and rectangular to rectangular only. Computation of convolution sum. Properties of convolution. System interconnection, system properties in terms of impulse response, step response in terms of impulse response.

Unit- III: Fourier series and Transforms (8)

Fourier series (FS) representation of periodic Continuous Time (CT) signals, Dirichlet condition for existence of Fourier series, orthogonality, basis functions, Amplitude and phase response, FS representation of CT signals using trigonometric and exponential Fourier series. Applications of Fourier series, properties of Fourier series and their physical significance, Gibbs phenomenon. FT of standard CT signals, Properties and their significance, Interplay between time and frequency domain using sinc and rectangular signals, Fourier Transform for periodic signals. DTFT, Definition, Frequency domain sampling , DFT, Properties of DFT, circular convolution, linear convolution

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Unit- V: Laplace Transform (8)

Definition of Laplace Transform (LT), Limitations of Fourier transform and need of Laplace transform, ROC, Properties of ROC, Laplace transform of standard periodic and aperiodic functions, properties of Laplace transform and their significance, Laplace transform evaluation using properties, Inverse Laplace transform based on partial fraction expansion, stability considerations in S domain, Application of Laplace transforms to the LTI system analysis.

Unit- VI: Application of Signal Processing in Robotics and Automation (8)

Applications of signal processing in robotic sectors: Autonomous navigation, robot teams or swarms of robots and target tracking. Remote health monitoring, neurobiological surveillance systems and fall detection for aged patients.

References:

1. Simon Haykins and Barry Van Veen, "Signals and Systems", Wiley India, 2 nd Edition.
2. M.J. Roberts "Signal and Systems", Tata McGraw Hill 2007.
3. John G. Proakis, Dimitris G. Manolakis, "Digital Signal Processing: Principles, Algorithms and applications" Fourth edition, Pearson Prentice Hall.
4. S. Salivahanan, C. Gnanpriya, "Digital Signal processing", McGraw Hill
5. Charles Phillips, "Signals, Systems and Transforms", Pearson Education, 3 rd Edition.
6. Peyton Peebles, "Probability, Random Variable, Random Processes", Tata McGraw Hill, 4 th Edition.
7. A. Nagoor Kanni "Signals and Systems", McGraw Hill, 2 nd Edition
8. Dr. Shaila Apte, "Digital Signal Processing" Wiley India Publication, second edition
9. K.A. Navas, R. Jayadevan, "Lab Primer through MATLAB", PHI
10. Li Tan, Jean Jiang, "Digital Signal Processing: Fundamentals and applications" Academic press

Savitribai Phule Pune University		
PEC-570D-ROB - Pneumatic and Hydraulic Control		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**CCE** : 50 Marks **End-Semester**: 50 Marks
Comprehensive Continuous Evaluation	**Closed book Test (CBT)**- 20 Marks **Open book Test (OBT)-** 10 **Marks Assignment/Presentation (A/P)**- 10 Marks **Research Papers /Survey Report (RPSR)** -10 Marks	

Unit- I: Fluid Power Principles and Hydraulic Pumps **(8)**

Introduction to Fluid power - Advantages and Applications - Fluid power systems - Types of fluids Properties of fluids and selection - Basics of Hydraulics - Pascal's Law - Principles of flow - Friction loss - Work, Power and Torque Problems, Sources of Hydraulic power : Pumping Theory, Pump Classification - Construction, Working, Design, Advantages, Disadvantages, Performance, Selection criteria of Linear and Rotary - Fixed and Variable displacement pumps - Problems.

Unit- II: Hydraulic Actuators and Control Components **(8)**

Hydraulic Actuators: Cylinders - Types and construction, Application, Hydraulic cushioning - Hydraulic motors - Control Components : Direction Control, Flow control and pressure control valves - Types, Construction and Operation - Servo and Proportional valves - Applications - Accessories : Reservoirs, Pressure Switches - Applications - Fluid Power ANSI Symbols - Problems.

Unit- III: Hydraulic Circuits and Systems **(8)**

Accumulators, Intensifiers, Industrial hydraulic circuits – Regenerative, Pump Unloading, Double- Pump, Pressure Intensifier, Air-over oil, Sequence, Reciprocation, Synchronization, Fail-Safe, Speed Control, Hydrostatic transmission, Electro hydraulic circuits, Mechanical hydraulic servo systems.

Unit- IV: Pneumatic and Electro Pneumatic Systems **(8)**

Properties of air - Perfect Gas Laws - Compressor - Filters, Regulator, Lubricator, Muffler, Air control Valves, Quick Exhaust Valves, time delay vale, shuttle valves, pressure relief valve, Pneumatic actuators, Design of Pneumatic circuit - Cascade method - Electro Pneumatic System - Elements - Ladder diagram - Problems, Introduction to fluidics and pneumatic logic circuits.

Unit- V: Trouble Shooting and Applications **(8)**

Installation, Selection, Maintenance, Trouble Shooting and Remedies in Hydraulic and Pneumatic systems, Design of hydraulic circuits for Drilling, Planning, Shaping, Surface grinding, Press and Forklift applications. Design of Pneumatic circuits for Pick and Place applications and tool handling in CNC Machine tools - Low cost Automation - Hydraulic and Pneumatic power packs.

References:

1. Anthony Esposito, "Fluid Power with Applications", Pearson Education 2005.
2. Majumdar S.R., " Oil Hydraulics Systems- Principles and Maintenance", Tata McGraw- Hill, 2001.
3. Anthony Lal, "Oil hydraulics in the service of industry", Allied publishers, 1982.
4. Dudelyt, A. Pease and John T. Pippenger, "Basic Fluid Power", Prentice Hall, 1987.
5. Majumdar S.R., "Pneumatic systems - Principles and maintenance", Tata McGraw Hill, 1995

Savitribai Phule Pune University		
PEC-571A-ROA - Simulation and Modeling		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**TW** : 50 Marks

Unit -I: Introduction modelling strategy **(8)**

System, environment, input and output variables, State variables; Static and Dynamic systems; Hierarchy of knowledge about a system and Modeling Strategy.

Introduction of Physical Modeling: Dimensions analysis, Dimensionless grouping of input and output variables of find empirical relations, similarity criteria and their application to physical models

Unit -II : Modelling of System with Known Structure **(8)**

Review of conservation laws and the governing equation for heat, mass and momentum transfer, Deterministic model-(a) distributed parameter models in terms of partial identification and their solutions and (b) lumped parameter models in terms of differential and difference equations, state space model, transfer functions block diagram and sub systems, stability of transfer functions, modelling for control

Unit -III: Optimizations and Design of Systems **(8)**

: Summary of gradient based techniques: Nontraditional Optimizations techniques genetic Algorithm (GA)-coding, GA operations elitism, Application using MATLAB: Simulated Annealing.

Unit- IV: Modeling using Neural Network and Expert Knowledge **(8)**

Neurons, architecture of neural networks, knowledge representation, learning algorithm. Multilayer feed forward network and its back propagation learning algorithm, Application to complex engineering systems and strategy for optimum output, Fuzzy sets, Membership functions, Fuzzy Inference systems, Expert Knowledge and Fuzzy Models, Design of Fuzzy Controllers

UNIT-V: Simulation of Engineering Systems: **(8)**

Monte-Carlo simulation, Inventory Control Simulation using Monte Carlo Technique, Simulation of continuous and discrete processes with suitable examples from engineering problems

References:

1. Zeigler B.P. Praehofer. H. and Kim I.G. "Theory of modeling and simulation", 2 nd Edition. Academic press, 2000
2. Ogata K , "Modern control Engineering" 3 rd edition. Prentice hall of India 2001
3. Jang J.S.R. sun C.T and Mizutani E,, "Neuro-Fuzzy and soft Computing ", 3 rd edition, Prentice hall of India, 2002
4. Shannon, R. E., "System Simulation: the Art and Science", Prentice Hall Inc. 1990
5. Pratab. R " Getting started with MATLAB" Oxford university Press 2009
6. Averill M Law and W D Kelton, "Simulation Modelling and analysis", 3rd edition McGraw- Hill

Savitribai Phule Pune University		
PEC-571B-ROA - MEMS and Microsystems		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**TW** : 50 Marks

Unit -I: Over view of MEMS and Microsystems **(8)**

Definition, historical development, properties, design and fabrication micro-system, microelectronics, working principle, applications and advantages of micro system. Substrates and wafers, silicon as substrate material, mechanical properties of Si, Silicon Compounds, silicon piezo resistors, Galium arsenide, quartz, polymers for MEMS, conductive polymers, Bio MEMS

Unit- II : Fabrication Processes **(8)**

:Photolithography, photo resist applications, light sources, ion implantation, diffusion Oxidation thermal oxidation, silicon dioxide, chemical vapour deposition, sputtering, deposition by epitaxy, etching, bulk and surface machining, LIGA process - LASER, Electron beam, Ion beam processes Mask less lithography

Unit -III: Micro Devices **(8)**

Sensors - classification - signal conversion ideal characterization of sensors micro actuators, mechanical sensors - measurands - displacement sensors, pressure sensor, flow sensors, Accelerometer , chemical and bio sensor - sensitivity, reliability and response of micro-sensor - micro actuators - applications.

Unit- IV: MEMS Accelerometers **(8)**

MEMS Accelerometers for Avionics, Piezoresistive Accelerometer Technology, MEMS Capacitive Accelerometer, MEMS Capacitive Accelerometer Process

UNIT-V: Microsystem Packaging **(8)**

Micro system packaging, packaging design levels of micro system packaging -Levels of packaging, interfaces in packaging - packaging technologies, Assembly of Microsystems

Packaging materials, Comparison between IC and MEMS packaging, Packaging technologies: Die preparation, surface bonding, wire bonding, sealing, Pressure sensor packaging

References:

1. Chang Liu, Foundations of MEMS, Prentice Hall (Pearson)
2. Tai - Ran Hsu, MEMS and Microsystems Design and Manufacture, Tata-McGraw Hill, New Delhi
3. Julian W. Gardner & Vijay K. Varadan, "Micro-sensors, MEMS and smart Devices", John Wiley & Sons,.
4. Julian W. Hardner Micro Sensors, Principles and Applications, CRC Press 1993.
5. Mark Madou , Fundamentals of Microfabrication, CRC Press, New York, 1997.
6. Mohamed Gad-el-Hak, MEMS Handbook, CRC press, 2006, ISBN : 8493-9138-5
7. Norio Taniguchi, Nano Technology, Oxford University Press, New York, 2003
8. Sami Franssila, Introduction to Micro fabrication, John Wiley & sons Ltd, 2004. ISBN:470-85106-6.

Savitribai Phule Pune University		
PEC-571C-ROA – Programming and Data structures		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**TW** : 50 Marks

Unit -I: C Programming Advanced Features **(8)**

Data Types, Instruction and its Types, Storage Classes, Operators and Hierarchy of Operations, Expressions in C, Control and Repetitive Statements, break, continue, Arrays, Strings.

Unit- II: Introduction to Data Structure **(8)**

Basic terminologies; introduction to basic data Structures: Arrays, linked list, trees, stack, queue, Graph; Data structure operations; Algorithm complexity: definition, types and notations .

Unit -III: Linear Data Structures **(8)**

Abstract Data Types (ADTs) - List ADT – array-based implementation – linked list implementation – singly linked lists- circularly linked lists- doubly-linked lists - applications of lists -Polynomial Manipulation - All operation (Insertion, Deletion, Merge, Traversal)

Unit -IV: Linear Data structures **(8)**

Stack ADT – Evaluating arithmetic expressions- other applications- Queue ADT – circular queue implementation - Double ended Queues - applications of queues

Unit- V: Sorting, Searching and Hash Techniques **(8)**

Sorting algorithms: Insertion sort - Selection sort - Shell sort - Bubble sort - Quick sort - Merge sort - Radix sort - Searching: Linear search -Binary Search Hashing: Hash Functions - Separate Chaining - Open Addressing - Rehashing Extendible Hashing

References:

1. Robert Kruise, C L Tondo and Bruce Leung, "Data Structures"
2. Brian W. Kernighan and Dennis M. Ritchie, “The C Programming Language”, 2nd Edition, Pearson Education, 1988.
3. Mark Allen Weiss, “Data Structures and Algorithm Analysis in C”, 2nd Edition, Pearson Education, 1997.
4. “Schaum’s Outline of Programming with C” by Byron Gottfried
5. Data structures: A Pseudocode Approach with C, 2nd edition,
6. R.F.Gilberg and B.A. Forouzan, “data Structures” Cengage Learning.
7. M.A.Weiss, Data structures and Algorithm Analysis in C, 2nd edition, Pearson.
8. A.M.Tanenbaum,Y. Langsam, M.J.Augenstein, Data Structures using C, Pearson.
9. R.Kruse, C.L.Tondo and B.Leung, Data structures and Program Design in C, 2nd edition, Pearson
10. R G Dromey, “How to Solve it by Computer” , Pearson Education

Savitribai Phule Pune University		
PEC-571D-ROA – Mobile and Autonomous Robots		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hours/Week **Practical:** 00 Hours/Week	03 00	**TW** : 50 Marks

Unit I: Introduction to Mobile Robots **(8)**

Tasks of mobile robots, robot manufacturers, type of obstacles and challenges, tele-robotics, philosophy of robotics, service robotics, types of environment representation. Ground Robots: Wheeled and Legged Robots, Aerial Robots, Underwater Robots and Surface Robots.

Unit II: Robot locomotion **(8)**

Types of locomotion, hopping robots, legged robots, wheeled robots, stability, maneuverability, controllability

Mobile robot kinematics and dynamics: Forward and inverse kinematics, holonomic and nonholonomic constraints, kinematic models of simple car and legged robots, dynamics simulation of mobile robots

Unit III: Sensors for localization **(8)**

Magnetic and optic position sensor, gyroscope, accelerometer, magnetic compass, inclinometer, GNSS and Sensors for navigation: tactile and proximity sensors, ultrasound rangefinder, laser scanner, infrared rangefinder, visual system .Current application and limitations of Mobile Robots.

Unit IV: Autonomous Robots **(8)**

The Basics of Autonomy (Motion, Vision and PID), Programming Complex Behaviors (reactive, deliberative, FSM), Robot Navigation (path planning), Robot Navigation (localization), Robot Navigation (mapping), Humanoid Robots and the DARPA challenge, Swarm Robotics, Telecheric robots, Robot Applications and Ethics.

Unit-V: Broad area Applications **(8)**

Automatic guidance, sowing, weeding, spraying and broad-acre harvesting, Horticulture: picking of fruits- Robot milking, sheep shearing, slaughtering, livestock inspection- Robots in construction, unsolved problems in construction, Future directions- Robots for hazardous applications, enabling technologies- Search and Rescue robotics: Disaster characteristics-Impact on Robots, medical robotics, cleaning robots, educational robotic platforms

References:

1. Bruno Siciliano, Oussama Khatib, ¯Springer Handbook of Robotics‖, Springer-Verlag
2. Yangsheng Xu, Huihuan Qian, Xinyu Wu, "Household and Service Robots", Elsevier Ltd, 2015.
3. R. Siegwart, I. R. Nourbakhsh, “Introduction to Autonomous Mobile Robots”, The MIT Press, 2011.
4. Aleksandar Lazinica, ¯Mobile Robots towards New Applications, Advanced Robotic Systems International, 2006.
5. Gregory Dudek, Michael Jenkin, ¯Computational Principles of Mobile Robotics‖, 2nd edition, Oxford University Press, 2010.
6. L Marques, A. de Almeida, Mo.Tokhi,G.S. Virk, ¯Advances in Mobile Robotics, World Scientific Publishing Co. Pte. Ltd. 2008.
7. K. S. Fu, R. C. Gonzalez, C. S. G. Lee, “Robotics - Control, Sensing, Vision and Intelligence”, McGraw Hill Int.
8. S.R. Deb, “Robotics Technology and Flexible Automation”, Tata McGraw Hill.
9. H. J. Warneck and R.D. Sehfart “Industrial Robots”, I.F.S. Pub., U. K.

Savitribai Phule Pune University		
RM-600-ROA- Research Methodology		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 05 Hours/Week **Practical:** 00 Hours/Week	05 00	**CCE** : 50 Marks End-sem: 50 Marks

Unit –I: Introduction **(8)**

Nature and objectives of research. Methods of Research: historical, descriptive and experimental, research process, research approaches, criteria for good research, problems faced by researchers

Unit –II: Research Design **(8)**

Meaning of research design, need of research design, features of good design, different research designs, basic principles of experimental designs, design of experiments.

Unit-III: Data Collection **(8)**

Types of data, methods and techniques of data collection, primary and secondary data, meta analysis, historical methods, content analysis, devices used in data collection, pilot study and pretest of tools, choice of data collection methods.

Unit-VI: Processing and Analysis of Data **(8)**

Use of statistics for data analysis, measures of central tendency, dispersion, skewness and relationship. Sampling distributions, sampling theory, determination of sample size, chi-square test, analysis of variance, multiple regression analysis, neural networks.

Unit-V: Decision Making Techniques **(8)**

Multi-attribute decision making techniques: Analytical Hierarchy Process (AHP), TOPSIS, Data Envelope Analysis (DEA), graph theory and matrix approach.

Multi-objective decision making techniques: Simulated annealing, Genetic algorithms.

Unit-VI: Interpretation and Report Writing **(8)**

Techniques of interpretation, precautions in interpretation, significance of report writing, different steps in report writing, layout of research report, mechanics of writing research report.

References:

1. C.R Kothari "Research Methodology" Wishwa Prakashan, ISBN: 8173280363
2. P.G Triphati "Research Methodology" Sultan Chand & Sons, New Delhi.
3. J. W Barnes, "Statistical Analysis for Engineers and Scientists" McGraw Hill, New York.
4. Ranjit Kumar "Research Methodology" Pearson Education, ISBN: 9788131704967
5. Rao R. V. "Decision making in the manufacturing environment using graph theory and fuzzy multiple attribute decision making" Springer-Verlag, London. ISBN: 1846288193
6. Rao S. S., "Optimization", Wiley Eastern, New Delhi, 1995. ISBN: 0471550345
7. Montgomery D.C., "Design and analysis of experiments", John Wiley & Sons, ISBN: 0470128666.

Savitribai Phule Pune University Second Year of Artificial Intelligence and Data Science (2024 Course)		
OJT-601-ROA- Internship/On Job Training (IN/OJT)		
Course Name: Internship/On Job Training (IN/OJT)	**Credits**	**Examination Scheme**
Practical: 10 Hours/Week	05	Term Work : 100 Marks

Course Objectives: The course aims to:
One of the main objectives of an internship is to expose one to a particular job and a profession or industry
While one might have an idea about what a job is like, he/she won't know until he/she actually performs if it's what he/she thought it was, if he/she has the training and skills to do it and if it's something he/she likes.
The objectives are,

- To put theory into practice.
- To expand thinking and broaden the knowledge and skills acquired through course work in the field.
- To relate to, interact with, and learn from current professionals in the field.
- To gain a greater understanding of the duties and responsibilities of a professional.
- To understand and adhere to professional standards in the field.
- To gain insight to professional communication including meetings, memos, reading, writing, public speaking, research, client interaction, input of ideas, and confidentiality.
- To develop the initiative and motivation to be a self-starter and work independently.

Course Outcomes: Upon successful completion of this course, students will be able to:

- Gain practical experience within industry in which the internship is done.
- Acquire knowledge of the industry in which the internship is done.
- Apply knowledge and skills learned to classroom work.
- Develop a greater understanding about career options while more clearly defining personal career goals.
- Experience the activities and functions of professionals.
- Develop and refine oral and written communication skills.
- Identify areas for future knowledge and skill development.
- Expand intellectual capacity, credibility, judgment, intuition.
- Acquire the knowledge of administration, marketing, finance and economics.

Course Description:

- Internship/On Job Training provide students the opportunity of hands-on experience that includes personal training, time and stress management, interactive skills, presentations, budgeting, marketing, liability and risk management, paperwork, equipment ordering, maintenance, responding to emergencies etc.
- An internship is the phase of time for students when they are trained for their skills, they are good at, and it gives them a chance to apply their knowledge practically in industries
- When should one start an engineering internship?
- It is mandatory for engineering students to enroll for an internship mostly during the Third semester of their graduate programme.

Internship Duration and Academic Credentials

- Student can take internship work in the form of Online/Offline mode from any of the Industry
- / Government Organization Internship Programmes approved by AICTE/UGC portals

- A full-time intern is expected to spend 40 - 45 hours per week on Internship, Training will result in about 360-540 hours of total internship duration.
- The minimum requirement regarding Internship duration should not be below 8 weeks

Type of Internship

- Industry/Government Organization Internship: Working directly with a company or government body.
- Research Internship: Focused on research projects, often in collaboration with academic institutions or R&D labs.
- Innovation/Entrepreneurship: Working on developing new products, processes, or even starting a venture.
- Social Internship: Engaging in community-based projects.

Assessment Details (TW and Practical)

- – Term work for 100 marks
- – A daily log submitted by the student and a work log signed by the office HoDs where the
- Student has interned will be considered towards the TW marking.

Indicative list of areas for OJT

- – Trade and Agriculture
- – Economy & Banking Financial Services and Insurance
- – Logistics, Automotive & Capital Goods
- – Fast Moving Consumer Goods & Retail
- – Information Technology/Information Technology Enabled Services & Electronics
- – Handcraft, Art, Design & Music
- – Healthcare & Life Science
- – Sports, Wellness and Physical Education
- – Tourism & Hospitality
- – Digitization & Emerging Technologies (Internet of Things / Artificial Intelligence / Machine
- Learning / Deep Learning / Augmented Reality / Virtual Reality etc.)
- – Humanitarian, Public Policy and Legal Services
- – Communication
- – Education
- – Sustainable Development
- – Environment
- – Commerce, Medium and Small-Scale Industries

Faculty Supervision: Students are usually assigned an internal faculty guide/mentor who supervises their internship activities. This faculty member acts as a teacher, mentor, and critic,and ensures the internship aligns with academic goals. External Supervision: In many cases, an external expert from the host organization also guides the student.

Documentation and Reporting:

- Joining Report: To be submitted within a specified time frame (e.g., one week from joining).
- Daily/Periodical Diary: Students are often required to maintain a daily or weekly record of their observations, work, and learning.
- Internship Report: A comprehensive report detailing the work done, learning outcomes, and achievements during the internship. This report needs to be duly signed by the company official and faculty mentor.
- Completion Certificate: Issued by the host organization upon successful completion.

Evaluation:

- Evaluation is typically done by the institute, often within a short period after the internship ends.
- It may involve presentations, viva-voce examinations, and assessment of the internship report and daily diary.
- Performance-based feedback from the industry mentor is usually a key component.

Savitribai Phule Pune University Second Year of Artificial Intelligence and Data Science (2024 Course)		
SEM-602-ROA- Technical Seminar II		
Course Name: Technical Seminar II	**Credits**	**Examination Scheme**
Practical: 6 Hours/Week	03	Term Work : 25 Marks Oral: 25 Marks

Course Description:

- Research Project seminar is the first stage of work on a master's thesis. During this course, students gain experience in the field of intellectual property and research ethics. They conduct patent searches and analyze related works to study the current state of the target area.
- Work on the "Research Project seminar" is carried out on the basis of the research and training laboratories of the Institute and the Scientific Library of the Institute/University and in close cooperation with the student's scientific supervisor.
- The aim of the "Research Project Seminar" is to prepare for the implementation of the Final Project and for master's thesis defense. It includes finding or developing methods and tools to solve a stated problem, taking into account the latest research and trends; clarification of requirements for the object under development; planning experiments and tests to prove the effectiveness of the proposed solution

Course Objectives:

- To provide students with the opportunity and support to improve their self-study skills using modern information technologies and apply new knowledge and skills in practice, including in new areas.
- To raise student's awareness in advanced methods of research and mastering the skills to apply them
- Teach students to find and critically analyze sources of information.
- **Develop** their ability to build logic of reasoning and statements based on the interpretation of data combined from various fields of science and technology, to make judgments based on incomplete data.
- Improve the student's academic writing experience.

Course Outcomes:

- Fundamental concepts and categories in the field of scientific research- ways of organizing and planning research
- relevant information sources that allow him or her to acquire new knowledge and skills in
- various fields
- advanced information technologies allowing us to acquire new knowledge in various fields
- features of the technical and scientific style of writing texts
- basic concepts of the culture of thinking, logic, rules for constructing reasoning and statements
- formal apparatus of the logic of constructing reasoning and statements
- evaluation criteria and methods of handling incomplete data
- Formulate the goals and objectives of scientific research;
- Search, evaluate and analyze information about the achievements of science and technology in the target area and beyond;
- Interpret data from different fields of science and technology;
- Build the logic of reasoning and statements;
- Write a text in a scientific or scientific and technical style, use the appropriate vocabulary;
- Create, design and edit text documents in accordance with the requirements of the organization or publisher;
- Plan a pilot study
- Methods of planning scientific research, taking into account the peculiarities of the professional area.

- Methods of collecting and analyzing information on the achievements of science and technology in the target area and beyond.
- proficiency in preparing publications on the topic of research
- Experience in data integration from different fields of science and technology and building evidence-based judgments.
- Methods of planning an experiment, taking into account the peculiarities of the field of professional activity.

Responsibility of the students:

- The Seminar should be carried out individually by each student.
- A student should identify the area or topics in recent trends and developments in consultation with the guide
- A student should report to his/her respective guide regularly (at least once in a week) and report the progress of the seminar work.
- A student should follow the timelines and deadlines and inform the supervisor in case of any difficulty/delay.
- Students should maintain the record of all the meetings, remarks given by guide/reviewers and progress of the work in the project diary. The project diary must be presented during each review presentation to the reviewers.
- A student should conduct the research ethically, adhere to the academic integrity standards, and cite sources whenever using any existing results
- A student should Incorporate constructive feedback to improve the quality and rigor of the Research
- For final examination, students should complete the Seminar Report in all aspects including formatting and citation.
- Each student should prepare the report, get it approved by his/her guide and submit the duly signed copy within the deadline.
- A student should invest time and effort in preparing for seminar presentations and the oral defense of the seminar

Course Contents:

1. Introductory lesson: clarification of the project topic, analysis of the assignment.
2. The structure of scientific texts: abstract, article, presentation, research report, master's thesis.
3. An analytical review on the research topic, its goals and objectives. Related works. Sources of information: open sources, journals, databases and collections of publishers. Citation rules. Scientific ethics. Plagiarism. Presentation and discussion of an in-depth analytical review on the research topic.
4. Scientific novelty. Intellectual property. Patent search: goals and objectives, patent databases, rules for compiling a patent search report.
5. Critical analysis of the related works. Identification and evaluation of methods used by other researchers. Choosing or developing your own method its rational.
6. Research Design Stage: clarification of the requirements for the object being developed (software, hardware and software system, technical product).
7. Formulation of criteria for the project goal achieving. Determination of ways to confirm the achievement of the set goal. Experimental study of the object under development.
8. Experiment planning.
9. Preliminary report on the Research Project. Discussion of the preliminary results of the project. Recommendations for improvement and revision.
10. Final assessment: Project defense in the form of a presentation as seminar

Savitribai Phule Pune University Second Year of Artificial Intelligence and Data Science (2024 Course)		
RPR-603-COM- Research Project Stage-I		
Course Name: Research Project Stage-I	**Credits**	**Examination Scheme**
Practical: 18 Hours/Week	09	Term Work : 25 Marks Oral: 25 Marks

Course Description:

The master's degree culminates in a research project of the student's own design. This research project is documented by a final research report or dissertation. The student's work is guided by an academic supervisor. Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. Students are expected to construct a research project that includes original research, deliberate and well considered methodological choices, and shows relevance to significant conversations within the discipline. The dissertation should represent the very best research and analysis a student can produce.

Course Objectives: Upon successful completion of this course, students will be able to:

1. Demonstrate an ability to plan a research project, such as is required in a research proposal prior to the launch of their work
2. Demonstrate an ability to comply with ethical, safety, and documentation processes appropriate to their project
3. Demonstrate expert knowledge in the subject of their research project, such as through a integrated literature survey
4. Demonstrate expert knowledge in the research methods appropriate to generating reliable data for their research questions
5. Demonstrate the ability to manage projects and to make constructive use of expertise associated with their project, while working as an independent learner
6. Demonstrate an ability to relate their original data to existing literature, or to create an novel synthesis of existing materials
7. Demonstrate an ability to assemble their findings into a substantial piece of writing that presents a clear thesis and a cohesive, evidence-based argument
8. Demonstrate an ability to balance description, analysis, and synthesis within their project report
9. Demonstrate an ability to reflect on the strengths and weaknesses of their research and methodology, with constructive advice on how they might improve their efforts in future work

Course Outcomes:

After successful completion of the course, learner will be able to:

CO 1: Demonstrate how to search the existing literature to gather information about a specific problem or domain.

CO 2: Identify the state-of-the-art technologies and research in the chosen domain, and highlight open problems that are relevant to societal or industrial needs.

CO 3: Evaluate various solution techniques to determine the most feasible solution within given constraints for the chosen dissertation problem.

CO 4: Apply software engineering principles related to requirements gathering and design to produce relevant documentation.

CO 5: Write a dissertation report that details the research problem, objectives, literature review, and solution architecture.

General Guidelines:

(a) The dissertation is a year-long project, conducted and evaluated in two phases. It can be carried out either in-house or within an industry as assigned by the department. The project topic and internal advisor (a faculty member from the department) are determined at the beginning of Phase I.

(b) Student is expected to complete the following activities in Phase-I:
i. Literature survey
ii. Problem Definition
iii. Motivation for study and Objectives
iv. Preliminary design / feasibility / modular approaches
v. Design of the research project

Savitribai Phule Pune University Second Year of Artificial Intelligence and Data Science (2024 Course)		
SEM-651-ROA - Seminar on project stage II		
Course Name: Seminar on project stage II	**Credits**	**Examination Scheme**
Practical: 08 Hours/Week	04	Term Work : 50 Marks Oral: 50 Marks

Course Objectives: Upon successful completion of this course, students will be able to:

1. To provide students with the opportunity and support to improve their self-study skills using modern information technologies and apply new knowledge and skills in practice, including in new areas.
2. To raise student's awareness in advanced methods of research and mastering the skills to apply
3. Them
4. Teach students to find and critically analyze sources of information.
5. Develop their ability to build logic of reasoning and statements based on the interpretation of data combined from various fields of science and technology, to make judgments based on incomplete data.
6. Improve the student's academic writing experience.

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

1. Formulate the goals and objectives of scientific research.
2. Search, evaluate and analyze information about the achievements of science and technology in the target area and beyond.
3. Interpret data from different fields of science and technology.
4. To build the logic of reasoning and statements.
5. Write a text in a scientific or scientific and technical style, use the appropriate vocabulary.

Responsibility of the students:

The Seminar should be carried out individually by each student based on their research project

- A student should identify the area or topics in from the topic selected for research project related recent trends and developments in consultation with the guide
- A student should report to his/her respective guide regularly (at least once in a week) and report the progress of the seminar work.
- A student should follow the timelines and deadlines and inform the supervisor in case of any difficulty/delay.
- Students should maintain the record of all the meetings, remarks given by guide/reviewers and progress of the work in the project diary. The project diary must be presented during each review presentation to the reviewers.
- A student should conduct the research ethically, adhere to the academic integrity standards, and cite sources whenever using any existing results
- A student should Incorporate constructive feedback to improve the quality and rigor of the research
- For final examination, students should complete the Seminar Report in all aspects including formatting and citation.
- Each student should prepare the report, get it approved by his/her guide and submit the duly signed copy within the deadline.
- A student should invest time and effort in preparing for seminar presentations and the oral defense of the seminar

Savitribai Phule Pune University Second Year of Artificial Intelligence and Data Science (2024 Course)		
RPR-652-ROA – Research Project II		
Course Name: Research Project II	**Credits**	**Examination Scheme**
Practical: 36 Hours/Week	18	Term Work : 150 Marks Oral: 50 Marks

Course Objectives: Upon successful completion of this course, students will be able to:

- Demonstrate an ability to plan a research project, such as is required in a research proposal prior to the launch of their work
- Ability to manage projects and to make constructive use of expertise associated with their project, while working as an independent learner
- Ability to relate their original data to existing literature, or to create an novel synthesis of existing materials
- Identify and formulate a problem of research interest in the chosen area of computing.

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

CO1: Undertake independent research that makes an original contribution to knowledge, or produces a novel synthesis of existing materials relevant to significant conversations in the discipline
CO2: Plan their project in advance, using a proposal to describe their undertaking, describe how it will be managed, and reflect upon its value
CO3: Relate their original research to existing literature on the subject and relate their work to general themes in their relevant scholarly literature
CO4: Assemble their rationale, methods, findings, and analysis into a substantial piece of writing that presents a clear thesis and a cohesive evidence-based argument or analysis
CO5: Reflect on the strengths and weaknesses of their research and methodology, understanding how they might improve their efforts in future work

General Guidelines

The student shall consolidate and complete the remaining part of the research work started in Semester

- This will consist of Selection of Technology, Installations, implementations, testing, Results, measuring performance, discussions using data tables per parameter considered for the improvement with existing/known algorithms/systems, comparative analysis, validation of results and conclusions.
- The student shall prepare the duly certified final report of dissertation in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute.
- The students are expected to validate their study undertaken by publishing it at standard platforms.
- The investigations and findings need to be validated appropriately at standard platforms like conference and/or peer reviewed journal.
- The student has to exhibit continuous progress through regular reporting and presentations and proper documentation of the frequency of the activities in the sole discretion of the PG coordination/Head of the department. The continuous assessment of the progress needs to be documented unambiguously.
- Supervisor Interaction: Minimum one meeting per week.
- Logbook: Maintain a record of work progress and supervisor comments.
- Ethics: No plagiarism, false results, or unethical practices allowed.
- Backup: Keep source code, datasets, and reports backed up securely.
- Submission Format: Soft copy (PDF) + Hard copy as per institute norms.

Key Components:

Implementation

- Complete development/simulation/testing of the system or model.
- Ensure correctness, efficiency, and validation of results.

Results & Analysis

- Include experimental setup, datasets used, and performance metrics.
- Graphs, tables, and comparison with existing techniques.
- Highlight key findings and their significance.

- ***Conclusion and Future Work***
  - Summarize outcomes, contributions, and applications.
  - Suggest extensions or improvements for future research.
- ***Paper Publication***
  - At least one paper (optional/encouraged) in peer-reviewed conference/journal.
  - Attach publication/proof as appendix (if available).
- ***Final Report Format***
  - Revised version of Stage 1 report with added implementation, results, and conclusion chapters.
  - Maintain academic writing standards and include all necessary references.
- ***Plagiarism Report***
  - Final version must again be checked and should not exceed 15% similarity.
- ***Evaluation Parameters***
  - Completeness and quality of implementation
  - Analysis and originality of results
  - Quality of documentation and adherence to format
  - Viv-voce performance and clarity of understanding
  - Contribution to knowledge or innovation