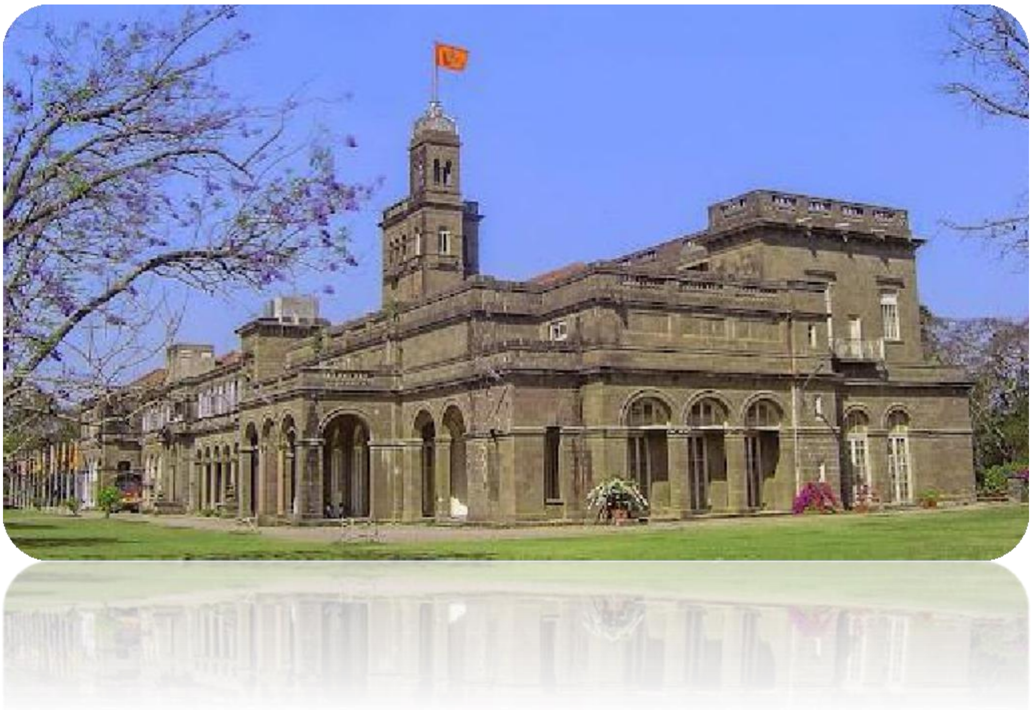
Savitribai Phule Pune University, Pune

Maharashtra, India

Faculty of Science and Technology



National Education Policy (NEP)-2020 Compliant Curriculum

SE – Second Year Engineering (2024 Pattern) – Revised in

Robotics and Artificial Intelligence

(With effect from Academic Year 2026-27)

Contents

Nomenclature

AEC	Ability Enhancement Courses
AICTE	All India Council for Technical Education
CO	Course Outcome
CEP	Community Engagement Project
CCE	Comprehensive Continuous Evaluation
HSSM	Humanities, Social Science, and Management
MDM	Multidisciplinary Minor
RAI	Robotics and Artificial Intelligence
MOOC	Massive Open Online Course
NPTEL	National Programme on Technology Enhanced Learning
NEP	National Education Policy
OE	Open Elective
PCC	Program Core Course
PEO	Program Educational Objectives
PSO	Program Specific Objectives
SWAYAM	Study Webs of Active Learning for Young Aspiring Minds
UGC	University Grant Commission
VEC	Value Education Course
VSE	Vocational Skill Course
WK	Knowledge and Attitude Profile

Preface by Board of Studies

Dear Students and Teachers,

We, the members of the Board of Studies – Mechanical Engineering, are very happy to present the Second Year **Robotics and Artificial Intelligence** syllabus, effective from the Academic Year 2026–27 (2024 Pattern). We are confident that you will find this syllabus both interesting and challenging. The present curriculum will be implemented for Second Year Engineering from the academic year 2026–27, and it will be subsequently extended to the Third and Final Years in the academic years 2027–28 and 2028–29, respectively.

Robotics and Artificial Intelligence is one of the most sought-after branches among engineering students, which necessitates continuous revision and up gradation of the syllabus. The **Robotics and Artificial Intelligence** program equips graduates with strong technical expertise in robotics, AI, and intelligent systems. They develop research-oriented analytical skills, ethical leadership, and lifelong learning abilities to design, simulate, and implement autonomous robotic solutions. The program emphasizes real-world applications, integrating AI with mechanical systems for industrial, healthcare, and automation challenges.

The revised syllabus aligns with the vision of **NEP-2020**, and conforms to the frameworks set by Savitribai Phule Pune University, AICTE New Delhi, UGC, and various accreditation agencies. It takes into account recent technological developments, innovations, and industry needs to ensure students are well-prepared for professional challenges.

Wherever applicable, additional learning resources such as NPTEL and SWAYAM links are provided at the end of each course. Students are encouraged to utilize these platforms for self-learning, engage in online courses, and undertake additional projects to enhance their knowledge and skill set. On successful completion, they are advised to submit their course certifications, which will further support and enrich their academic growth.

This curriculum is the result of collaborative efforts involving academic experts, industry professionals, and alumni to ensure relevance and excellence. It is designed not only to meet current industry expectations but also to prepare students for higher studies, research, and entrepreneurial ventures in the field **Robotics and Artificial Intelligence.**

We hope this curriculum inspires students to become technically competent professionals, responsible citizens, and contributors to the technological and sustainable advancement of society.

Dr. Pradeep A. Patil
Chairman
Board of Studies - Mechanical Engineering

Program Specific Outcomes (PSO)

PSO1: Foundation and Application of Robotics

Graduates will be able to apply kinematics, dynamics, control systems, and mechanical design to model, analyze, and develop robotic systems for industrial and real-world applications.

PSO2: Integration of Robotics with Artificial Intelligence

Graduates will demonstrate the ability to integrate AI techniques (such as machine learning, computer vision, and intelligent control) with mechanical systems to develop autonomous and adaptive robotic solutions.

PSO3: Design and Development of Intelligent Systems

Graduates will possess the skills to design, simulate, and implement intelligent robotic systems by combining mechanical components with embedded systems, sensors, actuators, and AI algorithms to address real-world problems in manufacturing, healthcare, and automation.

Program Educational Objectives (PEO)

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve.

PEO1: **Technical Expertise**	Graduates will demonstrate strong foundational and applied knowledge in Robotics and Artificial Intelligence, enabling them to solve complex engineering problems and contribute effectively to the modern industrial and technological landscape.
PEO2: **Research Orientation and Analytical Skills**	Graduates will be capable of adopting a scientific and research-based approach, employing mathematical models, engineering tools, and simulation techniques to design and evaluate intelligent robotic systems.
PEO3: **Ethical Leadership & Lifelong Growth**	Graduates will exhibit professionalism with ethical integrity, leadership, teamwork, and societal awareness, while demonstrating entrepreneurial thinking, a commitment to lifelong learning, and adaptability to technological changes for sustained career success.

Program Outcomes

Program Outcomes (POs) are statements that articulate what students are expected to know, understand, and be able to do by the time they graduate from the program. These outcomes are aligned with the overall educational objectives of the program and reflect the skills, knowledge, attitudes, and behaviors acquired by students throughout their academic journey. On successful completion of B.E. in **Robotics and Artificial Intelligence**, graduating students/graduates will be able to:

PO No.	Title	Program Outcome Description
PO1	Engineering Knowledge	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop the solution of complex engineering problems.
PO2	Problem Analysis	Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
PO3	Design / Development of Solutions	Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for public health and safety, whole-life cost, net zero carbon, culture, society and environment. (WK5)
PO4	Conduct Investigations of Complex Problems	Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)
PO5	Engineering Tool Usage	Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling, recognizing their limitations to solve complex engineering problems. (WK2 and WK6)
PO6	The Engineer and The World	Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7)
PO7	Ethics	Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
PO8	Individual and Collaborative Team Work	Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
PO9	Communication	Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.
PO10	Project Management and Finance	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects in multidisciplinary environments.
PO11	Life-Long Learning	Recognize the need for, and have the preparation and ability for: (i) independent and life-long learning, (ii) adaptability to new and emerging technologies, and (iii) critical thinking in the broadest context of technological change. (WK8)

Knowledge and Attitude Profile (WK)

WK No.	Title/Focus Area	Description
WK 1	Natural Sciences and Social Sciences	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.
WK 2	Mathematics and Data Analysis	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK 3	Engineering Fundamentals	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK 4	Engineering Specialist Knowledge	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK 5	Engineering Design and Environmental Considerations	Knowledge, including efficient resource use, environmental impacts, whole- life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK 6	Engineering Practice (Technology)	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK 7	Role of Engineering in Society	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Research and Critical Thinking	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK 9	Ethics and Inclusive Behavior	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability, etc., with mutual respect.

Reference: Self-Assessment Report (SAR) Format Undergraduate Engineering Programs Graduate Attributes and Professional Competencies Version 4.0 (GAPC V4.0) – (August 2024) Page 55-56

General Rules and Guidelines

Term	Definition
Course Outcomes (COs)	Course Outcomes are narrower statements that describe what students are expected to know and be able to do at the end of each course. These relate to the skills, knowledge, and behavior that students acquire throughout the course.
Assessment	Assessment is one or more processes, carried out by the institution, that identify, collect, and prepare data to evaluate the achievement of **Program Educational Objectives (PEOs)** and **Program Outcomes (POs)**.
Evaluation	Evaluation is one or more processes, performed by the **Evaluation Team**, to interpret the data and evidence gathered through assessment practices. It determines how well PEOs or POs are being achieved, and informs decisions for improvement.

Assessment and Evaluation:

Assessment and Evaluation shall be conducted in two parts: 1. Comprehensive Continuous Evaluation (CCE) 2. End-Semester Examination (ESE)		
Component	**Description**	**Marks**
Comprehensive Continuous Evaluation (CCE)	Conducted at institute level, covering all Units of the syllabus. The design and mark allocation follow the Continuous Assessment Sheet structure.	20 or 40
End-Semester Examination (ESE)	Conducted at university level, typically covering the entire syllabus through summative examination.	60
Total Marks per Subject		**100**

A) Comprehensive Continuous Evaluation (CCE): It can be conducted via Mode 1 or Mode 2

CCE Mode 1:

To design a Comprehensive Continuous Evaluation (CCE) scheme for a theory subject of 40 marks with the specified parameters, the allocation of marks and the structure can be as per continuous assessment sheet;

Savitribai Phule Pune University																			
Board of Studies (Mechanical and Automobile Engineering)																			
[CCE] Comprehensive Continous Evaluation [40 Marks Distribution]																			
Class: SE A												Subject: Fluid Mechanics							
Exam Seat No.	Roll No.	Name of Student	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Cumulative Sum			40 Marks Distribution			Marks obtained out
			Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Internal Test	Field Activity	Quiz	Internal Test	
			A	B	C	D	E	F	G	H	I	J	SUM(A+C+E+G+I)	SUM(B+D+F+H+J)					
			10	10	10	10	10	10	10	10	10	10	50	50	100	20	10	10	40
S9970160753	2020	AMOGH SHINDE	8	8	8	8	8	8	8	8	8	8	40	40	40	20	8	4	32

[CCE] Comprehensive Continous Evaluation [20 Marks Distribution]																			
Exam Seat No.	Roll No.	Name of Student	Unit 1		Unit 2		Unit 3		Unit 4				Cumulative Sum			20 Marks Distribution			Marks obtained out
			Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz			Field Activity	Quiz	Internal Test	Field Activity	Quiz	Internal Test	
			A	B	C	D	E	F	G	H			SUM(A+C+E+G+I)	SUM(B+D+F+H+J)					
			10	10	10	10	10	10	10	10			50	50	100	10	5	5	20
S9970160753	2020	AMOGH SHINDE	8	8	8	8	8	8	8	8			32	32	40	6.4	3.2	2	11.6

Field Activities / Home Assignments

Field activities and home assignments are essential components of experiential learning. Under this head, course projects, industrial visits, and guest lectures are to be incorporated. For each unit, one such activity should be designed and executed to reinforce theoretical learning through practical exposure.

1. Course Projects

Course Projects should be framed based on real-world problems relevant to the subject. Each course project must be communicated through one of the following modes. It is recommended to complete all the communication modes across different course projects:

- **Poster Presentation**
- **PowerPoint Presentation**
- **Model Making**
- **Field or Survey Report with Oral Presentation** (e.g., case study)
- **Submission of Digital Content** (e. g. Video Summary)

To evaluate these field activities, **assessment rubrics** should be designed. The rubrics should include criteria such as clarity, innovation, subject relevance, presentation skills, and technical content.

Note: Part of work of any co-curricular activities (relevant to subject contents) like national level project competitions, club activities, paper presentations, startup activities can be accepted as a course projects.

2. Industrial Visit

An industrial visit should be planned in alignment with the subject's scope and should particularly address advancements in the respective field. The purpose is to provide students exposure to actual engineering practices and systems. Assessment of industrial visits should be carried out using any of the following tools:

- **Quiz (based on the visit)**
- **Interactive video or oral discussion**
- **Submission of a detailed visit report**

3. Guest Lectures

Guest lectures should be relevant to the course and highlight advanced topics or recent trends in the field. Subject experts from academia or industry may be invited.

Assessment methods for guest lectures may include:

- **Quiz conducted post-lecture**
- **Attendance monitoring**
- **Evaluation of attentiveness and participation**

Rubrics can be developed, if possible, to objectively assess student involvement in guest lectures.

4. Quiz

Unit-wise quizzes should be planned and can be conducted either **online** (via LMS, Google Forms) or **offline**. Each quiz should include a **pool of 20 questions**, from which **students are required to attempt any 10**. The quizzes should be diversified across the following question types:

- **Simple Multiple-Choice Questions (MCQs)**
- **Numerical MCQs**
- **Image-based Questions**
- **Match the Following**
- **Fill in the Blanks**
- **Drag and Drop (using images or words)**

This variety ensures the assessment caters to different cognitive skills and learning styles.

5. Internal Tests

Two major internal tests should be conducted as follows:

1. **Midterm Examination**: This should cover **Unit I and Unit II**, and should include questions targeting **Bloom's Taxonomy Levels 2, 3, and 4** (UNDERSTAND, APPLY, and ANALYZE).
2. **End term Examination**: This should cover the **remaining units** and should also include questions mapped to **BL Levels 2, 3, and 4**.

CCE Mode 2:

Comprehensive Continuous Evaluation (CCE) scheme in this mode for a theory subject of 40 marks with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr. No.	Parameters	Marks	Coverage of Units
1	Unit Test	16 Marks	Unit 1 & Unit 2 (8 Marks/Unit)
2	Assignments/Case Study	16 Marks	Unit 3 & Unit 4 (8 Marks/Unit)
3	Seminar Presentation/ Open Book Test/ Quiz	08 Marks	Unit 5

CCE of 20 marks based on all the Units of course syllabus to be scheduled and conducted at institute level. To design a CCE scheme for a theory subject of 20 marks with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr. No.	Parameters	Marks	Coverage of Units
1	Unit Test	10 Marks	Unit 1 & Unit 2 (5 Marks/Unit)
2	Seminar Presentation/ Open Book Test/ Assignments/ Case Studies	10 Marks	Unit 3 & Unit 4 (5 Marks/Unit)

1. **Unit Test:**

   Format: Questions designed as per Bloom's Taxonomy guidelines to assess various cognitive levels (Remember, Understand, Apply, Analyze, Evaluate, and Create).
   Implementation: Schedule the test after completing Units 1 and 2. Ensure the question paper is balanced and covers key concepts and applications.

   - *Sample Question Distribution:*
     1. Remembering (2 Marks): Define key terms related to [Topic from Units 1 and 2].
     2. Understanding (2 Marks): Explain the principle of [Concept] in [Context].
     3. Applying (2 Marks): Demonstrate how [Concept] can be used in [Scenario]
     4. Analyzing (3 Marks): Compare & contrast [Two related concepts] from Units 1 and 2
     5. Evaluating (3 Marks): Evaluate the effectiveness of [Theory/Model] in [Situation].

2. **Assignments / Case Study:** Students should submit one assignment or one Case Study Report based on Unit 3 and one assignment or one Case Study Report based on Unit 4.

   i. ***Format*:** Problem-solving tasks, theoretical questions, practical exercises, or case studies that require in-depth analysis and application of concepts.

ii. ***Implementation:*** Distribute the assignments or case study after covering Units 3 and 4. Provide clear guidelines and a rubric for evaluation.

3. **Seminar Presentation:**

   i. ***Format:*** Oral presentation on a topic from Unit 5, followed by a Q&A session.
   ii. ***Deliverables*:** Presentation slides, a summary report in 2 to 3 pages, and performance during the presentation.
   iii. ***Implementation:*** Schedule the seminar presentations towards the end of the course. Provide students with ample time to prepare and offer guidance on presentation skills.

4. **Open Book Test:**

   i. ***Format:*** Analytical and application-based questions to assess depth of understanding. ***Implementation****:* Schedule the open book test towards the end of the course, ensuring it covers critical aspects of Unit 5

5. **Quiz:**

   i. ***Format:*** Quizzes can help your students practice existing knowledge while stimulating interest in learning about new topic in that course. You can set your quizzes to be completed individually or in small groups.
   ii. ***Implementation****:* Online tools and software can be used create quiz. Each quiz is made up of a variety of question types including multiple choice, missing words, true or false etc.

- ***Example Timeline for conducting CCE:***

  1. Weeks 1-4 : Cover Units 1 and 2
  2. Week 5 : Conduct Unit Test (12 marks)
  3. Weeks 6-8 : Cover Units 3 and 4
  4. Week 9 : Distribute and collect Assignments / Case Study (12 marks)
  5. Weeks 10-12 : Cover Unit 5
  6. Week 13 : Conduct Seminar Presentations or Open Book Test or Quiz (6 marks)

- ***Evaluation and Feedback:***

1. Unit Test: Evaluate promptly and provide constructive feedback on strengths and areas for improvement.
2. Assignments / Case Study: Assess the quality of submissions based on the provided rubric. Offer feedback to help students understand their performance.
3. Seminar Presentation: Evaluate based on content, delivery, and engagement during the Q&A session. Provide feedback on presentation skills and comprehension of the topic.
4. Open Book Test: Evaluate based on the depth of analysis and application of concepts. Provide feedback on critical thinking and problem-solving skills.

B) **<u>End-Semester Examination (ESE)</u>**

Detailed Scheme for 60 Marks: Unit-Wise Allocation (12 Marks per Unit): Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation.

Detailed Scheme for 30 Marks: Unit-Wise Allocation (10 Marks per Unit): Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation.

Question Paper Design:

The following structure is to be followed for designing an ESE for a **theory subject of 60 marks** covering all **5 units** of the syllabus, with **questions set as per Bloom's Taxonomy** guidelines and **12 marks allocated per unit.**

1. Balanced Coverage

Ensure balanced coverage of all units with questions that assess different **cognitive levels of Bloom's Taxonomy**:

a) **Remembering**: Basic recall of facts and concepts.
b) **Understanding**: Explanation of ideas or concepts.
c) **Applying**: Use of information in new situations.
d) **Analyzing**: Drawing connections among ideas.
e) **Evaluating**: Justifying a decision or course of action.
f) **Creating**: Producing new or original work (if applicable).

2. Detailed Scheme

Unit-Wise Allocation: **12 Marks per Unit**

Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to **Bloom's Taxonomy guidelines** for cognitive skills evaluation.

NEP 2020 Compliant Curriculum Structure

Second Year Engineering (2024 Pattern) Revised

Robotics & Artificial Intelligence

Level 5.0															
Course Code	**Course Type**	**Course Name**	**Teaching Scheme (Hrs./week)**			**Examination Scheme and Marks**						**Credits**			
			Theory	**Practical**	**Tutorial**	**CCE***	**End-Sem**	**Term work**	**Practical**	**Oral**	**Total**	**Theory**	**Tutorial**	**Practical**	**Total**
Semester III															
PCC201RAI	Major Course	Basics of Robotics & AI	3			40	60				100	3			3
PCC202RAI	Major Course	Materials and Manufacturing	3			40	60				100	3			3
PCC203RAI	Major Course	Analog & Digital Electronics	3			40	60				100	3			3
PCC204RAI	Major Course	Analog & Digital Electronics Lab		2					50		50			1	1
MDM221RAI	Multidisciplinary Course	Mathematics for Intelligent Systems	3			40	60				100	3			3
MDM222RAI	Multidisciplinary Course	Computer Programming Lab		2					50		50			1	1
	Open Elective	Open Elective-I	2			20	30				50	2			2
VSE231RAI	Vocational and Skill Enhancement Course	Computer Aided Design Lab		2					25		25			1	1
HSSM232RAI	Entrepreneurship/ Management Course	Entrepreneurship Development & Innovation	1			25					25	1			1
VEC233RAI	Value Education Course	Sustainable Development	2			20	30				50	2			2
CEP241RAI	Community Engagement Project	Community Engagement Project		4				50			50			2	2
Total			**17**	**10**	**0**	**225**	**300**	**50**	**125**		**700**	**17**	**0**	**5**	**22**

CCE*: Comprehensive Continuous Evaluation

Note: Students can opt for Open Electives offered by different faculties such as Arts, Science, Commerce, Management, Humanities, or Inter-Disciplinary Studies.

Example – Open Elective I: Students may choose courses like *Financial Accounting*, *Digital Finance*, or *Digital Marketing* from the Commerce and Management faculty.

NEP 2020 Compliant Curriculum Structure

Second Year Engineering (2024 Pattern) Revised

Robotics & Artificial Intelligence

Level 5.0															
Course Code	**Course Type**	**Course Name**	**Teaching Scheme (Hrs./week)**			**Examination Scheme and Marks**						**Credits**			
			Theory	**Practical**	**Tutorial**	**CCE***	**End-Sem**	**Term work**	**Practical**	**Oral**	**Total**	**Theory**	**Tutorial**	**Practical**	**Total**
Semester IV															
PCC251RAI	Major Course	Sensors for Industrial Robotics	3			40	60				100	3			3
PCC252RAI	Major Course	Kinematics of Robot	3			40	60				100	3			3
PCC253RAI	Major Course	Mechanics of Materials	3			40	60				100	3			3
PCC254RAI	Major Course	Sensors for Industrial Robotics Lab		2					50		50			2	2
PCC255RAI	Major Course	Materials Testing and Characterization Lab		2					50		50			1	1
MDM271RAI	Multidisciplinary Course	Biomechanics and Biomaterials	2			50					50	2			2
	Open Elective	Open Elective-II	2			20	30				50	2			2
VSE281RAI	Vocational and Skill Enhancement Course	CNC and System Simulation Lab		2					50		50			1	1
AEC282RAI	Ability Enhancement Course	Technical Communication & Soft Skills		2	1			50			50		1	1	2
HSSM283RAI	Entrepreneurship/ Management course	Entrepreneurship Essentials	2			50					50	1			1
VEC284RAI	Value Education Course	Constitution of India and Universal Human Values	2			20	30				50	2			2
Total			**17**	**8**	**1**	**260**	**240**	**50**	**150**	**0**	**700**	**16**	**1**	**5**	**22**

CCE*: Comprehensive Continuous Evaluation

Example – Open Elective II: Students may choose courses like *Financial Accounting*, *Digital Finance*, or *Digital Marketing* from the Commerce and Management faculty.

Important Note: Min. 1 to Max. 2 Hrs. per batch of 20-25 students to be assigned for ***CCE** and to be considered in teaching load of concerned faculty (Only applicable for Mode I).

Savitribai Phule Pune University, Pune

Maharashtra, India

SE - Robotics and Artificial Intelligence (2024 Pattern) Revised

Semester III Courses

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
PCC-201-RAI: Basics of Robotics and AI				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**3 Hours/Week**	**3**	**CCE**	**40 Marks**
Practical	**NA**		**End-Semester**	**60 Marks**

Prerequisite:

Basic Electrical Engineering (ESC-102-ELE),
Basic Electronics Engineering (ESC-102-ETC)

Course Objectives:

The student will be able

1. To develop a solid understanding of the foundational principles, components, and history of robotics and AI.
2. To gain knowledge of robot design, including kinematics, dynamics, and control techniques used to operate robots.
3. To understand how AI and machine learning algorithms are applied to robotics to enable autonomous decision-making and problem-solving.
4. To understand how AI algorithms are integrated into robotics to create autonomous systems capable of real-time decision-making and environmental interaction.
5. To gain hands-on experience with robotics systems and AI tools by designing, building, and programming robots and AI-driven applications.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: UNDERSTAND different types of robots and robot grippers, and compare & classify types of Sensors, Drives & Grippers.

CO2: ANALYZE the fundamental methods of robot programming and critically compare their suitability for different industrial applications.

CO3: INTERPRET robot kinematics principals for understanding manipulators tracking.

CO4: EVALUATE awareness and a fundamental understanding of AI techniques in intelligent agents, artificial neural networks.

CO5: IDENTIFY basic principles of AI in solutions that require problem solving, inference, perception, knowledge representation and learning by understanding AI, its current scope and limitations, and societal implications.

Course Contents

Unit I	Introduction to Robotics	(08 Hours)

Basics of Robotics: Definitions, Laws & Robotics-classification with respect to geometrical configuration (Anatomy).

Industrial Robots: Industrial robot specifications, Selection based on the application, Controlled system & chain type: Serial manipulator & Parallel Manipulator, Components of Industrial robotics-precession of movement, resolution, accuracy & repeatability, Advances in Industrial Robotics Technology Robot.

Applications: Material transfer and machine loading/unloading, Processing operations assembly and inspection.

Real World Assignment:

1. Select three industrial robot and compare their geometric configuration, DOF and workspaces for electronics assembly and fast pick and place operation.
2. Research real robot model and compare specification such as reach, payload, and repeatability for arc welding and palletizing operation.
3. Implement advanced technology in collaborative robots which impacting on Industry 4.0.

Exemplary: Surgical robotics, Warehouse autonomous mobile robots, Exoskeletons for rehabilitation, Robotic palletizing and de-palletizing in logistics, Bulk material handling in construction/mining.

Unit II	Sensors, Controllers, and Programming and Languages	(07 Hours)

Sensors: Characteristics of sensing devices, Criterion for selections of sensors, Classification & applications of sensors.

Controllers: Introduction and types of Controllers and introduction to close loop controller.

Programming and Languages: Methods of robot programming, Introduction to various languages such as RAIL and VAL II, etc.

Real World Assignment:

1. Identify and select sensors for industrial automation such as object detection, robotic arm positioning etc.
2. Model a temperature control system using ON/OFF control, PID control, Fuzzy logic control and compare performance.
3. Explore robot programming language and integration for a pick and place operation.

Exemplary: Autonomous mobile robots, Collaborative robot (Cobot) Assembly, Precision electronics assembly, Metal object sorting, Machine loading/unloading, Automated bin picking.

Unit III	Drives and Grippers	(07 Hours)

Drives: Types of drives, Advantages and Disadvantages of each type, Selection / suitability of drives for Robotic application.

Grippers: Classification of Grippers, Mechanical Gripper-Grasping force, Mechanisms for actuation, Magnetic gripper, Vacuum cup gripper, Considerations in gripper selection & design.

Real World Assignment:

1. Understand and compare the electric, pneumatic and hydraulic drive systems in various robots and make presentation.
2. Calculate the minimum gripping force needed to hold a 1 kg steel block (vertical lift) and slippery plastic tube (horizontal transfer).
3. Build a suction gripper using Syringe (actuator) and plastic bottle.

Exemplary: High-speed pick & place (Electronics Assembly), Heavy payload material handling (Automotive body welding, Precision assembly (e.g., PCB insertion), Palletizing heavy boxes (Logistics).

Unit IV	Introduction to Artificial Intelligence	(07 Hours)

Overview of Artificial Intelligence: Foundations, Scope, Problems, and approaches of AI.

Intelligent Agents: Reactive, Deliberative, Goal-driven, Utility-driven, and teaching agents, Artificial Intelligence programming techniques.

Exemplary: Autonomous vacuum cleaner (e.g., Roomba), Adaptive process optimization in manufacturing, Robotic exploration & mapping, Autonomous navigation for delivery robots, Goal-driven path planning for automated guided vehicles.

Real World Assignment:

1. Explore how AI solves real-world problems and identify 3 AI application for e.g. predictive maintenance, fraud detection, and robotic surgery and make report on it.
2. Use python and simulate reactive agent (obstacle avoiding robot) and goal driven agent (path finding) a short demo and explanation.
3. Compare AI (e.g., Chat GPT) and human responses to the same 5 questions (e.g., essay writing, math problems).

Unit V	Problem-solving Approaches and Knowledge Representation and Reasoning	(07 Hours)

Problem-solving Approaches: Forward and backward, State-space, Blind, Heuristic, Problem reduction, Alpha-beta pruning, Minimax, Constraint propagation, Neural, Stochastic, and Evolutionary search algorithms, Sample applications.

Knowledge Representation and Reasoning: Ontologies, Foundations of knowledge representation and reasoning, Representing, and reasoning about objects, relations, events, actions, time, and space; predicate logic, Situation calculus, Description logics, Reasoning with defaults, Reasoning about knowledge, Sample applications.

Real World Assignment:

1. Design an AI system that solves logistics problems in a smart factory using search algorithms and knowledge graphs.
2. Identify Algorithm Olympics and compare three search method for robot path finding, task scheduling, and dynamic replanning.
3. Apply the crisis response simulation with problem reduction, heuristic search, situation calculus.

Exemplary: A* Algorithm for warehouse AGV navigation, Breadth-First Search (BFS) for robotic exploration, Genetic algorithm with hebbian learning for navigation, Constraint propagation in robot assembly.

Learning Resources

Text Books:

1. Chandra, V. S. S., & Anand, H. S. (2014). *Artificial intelligence & machine learning*. PHI Publishers.
2. Craig, J. J. (2005). *Introduction to robotics (3rd Ed.)*. Pearson Education.
3. Ghoshal, A. (2006). *Robotics: Fundamental concepts & analysis*. Oxford University Press.
4. Luger, G. F. (2008). *Artificial intelligence (5th Ed.)*. Pearson.
5. Mittal, R. K., Nagrath, I. J., & Gupta, V. (2003). *Robotics & control*. Tata McGraw-Hill.
6. Negnevitsky, M. (2011). *Artificial intelligence: A guide to intelligent systems (3rd Ed.)*. Pearson.
7. Pratihar, D. K. (2019). *Fundamentals of robotics*. Narosa Publishing House.

Reference Books:

1. Klafter, R. D., Chmielewski, T. A., & Negin, M. (2009). *Robotic engineering: An integrated approach*. Pearson Education.
2. Groover, M., Weiss, M., Nagel, R. N., Odrey, N., & Dutta, A. (2012). *Industrial robotics (2nd Ed.)*. McGraw Hill Education.
3. Nikku, S. B. (2020). *Introduction to robotics: Analysis, control, applications (3rd Ed.)*. John Wiley & Sons.
4. Saha, S. K. (2014). *Introduction to robotics*. McGraw Hill Education.
5. Russell, S., & Norvig, P. (2003). *Artificial intelligence: A modern approach*. Prentice Hall.
6. Aleksander, I., & Burnett, P. (1987). *Thinking machines*. Oxford University Press.
7. Bench-Capon, T. J. M. (1990). *Knowledge representation: An approach to artificial intelligence*. Academic Press.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Introduction to Robotics
   https://nptel.ac.in/courses/107106090
2. NPTEL Course: Robotics: Basics and Selected Advanced Concepts
   https://nptel.ac.in/courses/112108298
3. Coursera Course: Introduction to Artificial Intelligence (AI)
   https://www.coursera.org/learn/introduction-to-ai

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
PCC-202-RAI: Materials and Manufacturing				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**3 Hours/Week**	**3**	**CCE**	**40 Marks**
Practical	**NA**		**End-Semester**	**60 Marks**

Prerequisite:

Engineering Mechanics (ESC-104-CVL)

Course Objectives:

The students will be able

1. To provide foundational knowledge of material behavior, crystal structures, and their impact on mechanical properties.
2. To develop practical skills in material testing methods (tensile, hardness, impact tests) and data interpretation for material evaluation.
3. To impart hands-on experience in basic manufacturing processes (casting, welding, sheet metal forming) and their engineering applications.
4. To analyze manufacturing defects in casting, welding, and forming processes, and formulate preventive/corrective strategies.
5. To introduce robotic applications in modern manufacturing and assess their role in automation and efficiency.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: ANALYZE the crystal structures, atomic arrangements, and deformation mechanisms in engineering materials to predict their mechanical behaviour.

CO2: EVALUATE material properties and failure behaviour using mechanical testing methods and INTERPRET test results such as DBTT, fracture surfaces, and stress-strain curves.

CO3: APPLY casting principles including pattern design, riser sizing, and defect identification, and COMPARE metal forming processes for given applications.

CO4: DESIGN sheet metal operations and **SELECT** appropriate metal joining processes based on application requirements.

CO5: INTEGRATE robotic systems with sensors, vision systems (2D/3D), and NDT techniques for manufacturing automation, material handling, inspection, and data-driven production planning.

Course Contents		
Unit I	**Structures and Deformation of Materials**	**(08 Hours)**

Material Structures: Classification of engineering materials, Study of crystal structures, Defects in crystals – point defects, line defects (dislocations), Characteristics of dislocations.

Deformation of Materials: Elastic and plastic deformation, Slip Systems, Twinning, Work hardening, Strengthening mechanisms.

Phase Transformation: Nucleation and growth of crystals, Diffusion mechanisms, Basics of phase diagram, Gibb's phase rule, Lever rule, Iron - Iron carbide phase diagram, Phase transformations in steels and cast iron.

Real World Assignment:

1. Examine a broken metal object (spoon, key, and bracket) to identify ductile vs. brittle fracture and find visual evidence of slip lines or twinning.
2. Build 3D models of SC, BCC, and FCC unit cells, photograph them, and calculate the Atomic Packing Factor (APF) with step-by-step derivation.
3. Bend copper wire (cold-worked) and annealed copper to compare stiffness/ductility, and explain how strain hardening strengthens by impeding dislocation movement.
4. Research and construct a labeled binary phase diagram (e.g., Cu-Ni or Pb-Sn), mark the liquidus, solidus, and eutectic point, and explain its significance.

Exemplary: Precipitation hardening of aircraft aluminum, Strengthening mechanisms in automotive aluminum, Twinning in magnesium alloy golf clubs, Failure analysis of a broken gear tooth.

Unit II	Material Testing and Characterization	(07 Hours)

Material Testing and Behaviour: Heat Treatment of steels, Tensile, Compression, Impact, Bending, and Fatigue tests- testing parameters, factors affecting, Hardness test, Creep and stress rupture–mechanism of creep, Fracture of metals – Ductile fracture, Brittle fracture, Ductile to Brittle Transition Temperature (DBTT).

Non-Destructive Testing: Eddy current test, Ultrasonic testing, X-ray Radiography testing (Principle and Applications only), SEM, TEM and X-ray diffraction.

Real World Assignment:

1. Source fractured metal samples, photograph fracture surfaces, and identify failure mode by observing visual features like dimples, shear lips, cleavage facets, and river patterns.
2. Obtain stress-strain curves for three different materials, calculate elastic modulus, yield strength, UTS, and ductility, and recommend the best material for a specific application based on property trade-offs.
3. Conduct Charpy impact tests on PVC, aluminum, and steel at different temperatures (-20°C to 100°C). Analyze ductile-to-brittle transitions.
4. Find research images from Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and X-Ray Diffraction (XRD) patterns for a metal sample, and explain what microstructural information each technique provides.

Exemplary: Ultrasonic testing and bend fatigue evaluation in wind turbine blade inspection, Impact testing and X-ray radiography in automotive wheel certification, Magnetic particle testing detects stress-induced microcracks.

Unit III	Casting and Metal Forming Processes	(07 Hours)

Casting: Cold & Hot working processes, Introduction to sand casting process- principle, process parameters, classifications, Casting equipment and tools - applications and limitations, Die-casting – hot chamber and cold chamber, Centrifugal casting, Squeeze casting, Defects in castings.

Metal Forming: Rolling and its process, Forging operations, Extrusion process, Wire and Tube drawing– Equipment and tools, process parameters, characteristics, defects, applications and limitations.

Real World Assignment:

1. Visit a local foundry or watch a video of sand casting, identify the pattern, mold, core, gating system, and riser, and explain their functions.
2. Examine cast metal objects (e.g., engine blocks, cookware, and pipe fittings) and identify common defects like shrinkage cavities, porosity, cold shuts, or misruns.
3. Explore the use of centrifugal casting to manufacture hollow rotating shafts or wheels for mobile robots.
4. Compare extrusion, forging, and rolling to determine the most effective forming process for a robot chassis.

Exemplary: Squeeze casting for lightweight robotic manipulators, Centrifugal casting of robotic wheel hubs, Forged gears and shafts in robotic transmissions, Tube drawing for hydraulic cylinders in robotic excavators or industrial arms.

Unit IV	Sheet Metal and Metal Joining Processes	(07 Hours)

Sheet Metal Processes: Introduction, Types of forming processes, Development drawing of simple sheet metal object, Sheet forming processes – equipment and tools, process parameters, characteristics, defects, applications and limitations.

Metal Joining Processes: Gas welding, Arc welding, Resistance welding, Solid state joining, Brazing and Soldering, Adhesive bonding processes – principles, equipment, process parameters, tools and accessories, joint characteristics, defects, applications, and limitations.

Real World Assignment:

1. Explore how sheet metal is used to form lightweight, wearable robotic support structures/ Design of a sheet-metal based Mobile Robot Chassis.
2. Bend a sheet metal strip at different radii and angles, observe springback effect, and calculate the bend allowance for a given thickness and angle.
3. Research robotic laser welding applications (e.g., battery tab welding for EVs, sensor housings), explain the advantages over traditional methods, and identify critical process parameters.

Exemplary: Sheet metal forming tooling design for repetitive robot part production, Sheet-metal based mobile robot chassis, and Sheet metal bracket for robotic arm mounting, Resistance spot welding for assembly of sheet metal robot frames.

Unit V	Application of Robotics in Manufacturing	(07 Hours)

Application of Robotics in Manufacturing: Material transfer, Machine loading/unloading, Collaborative works, Assembly line, Supply chain automation, Inspection & maintenance.

Real World Assignment:

1. Design a robotic work cell for loading/unloading a CNC machine, specifying robot reach, gripper type, part orientation, and cycle time.
2. Study AGV/AMR navigation methods (SLAM, magnetic tape, QR codes) and fleet management in a warehouse or factory setting.
3. Propose a model for using IoT-enabled robots for real-time inventory tracking, storage, and dispatch.

Exemplary: Robotic machine loading/unloading system for lathe or milling machine, Vision-based robotic inspection system for detecting surface defects, Autonomous Mobile Robot (AMR) system for intra-plant logistics.

Learning Resources

Text Books:

1. Callister, W. D. (2006). *Materials science and engineering (8th Ed.)*. John Wiley & Sons.
2. Groover, M. P. (2010). *Fundamentals of modern manufacturing: Materials, processes, and systems (4th Ed.)*. John Wiley & Sons.
3. Kalpakjian, S., & Schmid, S. R. (2013). *Manufacturing engineering and technology (7th Ed.)*. Prentice Hall.
4. Kodgire, V. D., & Kodgire, S. V. (2022). *Material science & metallurgy for engineers*. Everest Publication.
5. Raghavan, V. (2006). *Materials science and engineering (5th Ed.)*. Prentice Hall of India.

Reference Books:

1. Askland, D. R., & Phule, P. P. (2002). *The science and engineering of materials (4th Ed.)*. Thomson Engineering.
2. Avner, S. H. (1974). *Introduction to physical metallurgy (2nd Ed.)*. McGraw-Hill.
3. Bhargava, A. K., & Sharma, C. P. (2011). *Mechanical behaviour & testing of materials*. PHI Learning Private Ltd.
4. Rao, P. N. (2017). *Manufacturing technology – Volume I: Foundry, forming and welding (5th Ed.)*. Tata McGraw-Hill Education.
5. Reed-Hill, R. E., & Abbaschian, R. (2009). *Physical metallurgy principles (4th Ed.)*. Cengage Learning.
6. Sharma, P. C. (2014). *Textbook of production technology (8th Ed.)*. S. Chand and Company Pvt. Ltd.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Introduction to Materials Science and Engineering
   https://onlinecourses.nptel.ac.in/e-learning/preview/noc25_mm17

2. NPTEL Course: Fundamentals of Manufacturing Processes
   https://nptel.ac.in/courses/112107219

3. Coursera Course: Fundamentals of Materials Science
   https://www.coursera.org/learn/fundamentals-of-materials-science

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
PCC-203-RAI: Analog and Digital Electronics				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**3 Hours/Week**	**3**	**CCE**	**40 Marks**
Practical	**NA**		**End-Semester**	**60 Marks**

Prerequisite:

Basic Electrical Engineering (ESC-102-ELE),
Basic Electronics Engineering (ESC-101-ETC)

Course Objectives:

The student will be able

1. To recall and recognize construction and characteristics of JFETs and MOSFETs and differentiate with BJT.
2. To demonstrate and analyze operational amplifier circuits and their applications.
3. To describe, illustrate and analyze combinational logic circuits, simplification of algebraic equations using Karnaugh Maps and Quine McClusky techniques.
4. To describe and design decoders, encoders, digital multiplexers, adders and subtractors, binary comparators, latches and master slave flip-flops.
5. To explain and design registers, counters, A/D and D/A converters.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: ANALYZE and design Op-Amp based application circuits like peak detectors, active filters, comparators, and relaxation oscillators.

CO2: SIMPLIFY and implement combinational logic circuits using K-map, Quine-McCluskey method, and HDL, while addressing timing hazards.

CO3: DESIGN and verify data processing circuits such as decoders, multiplexers, encoders, parity generators, and ALUs using both gates and HDL.

CO4: DESIGN and simulate edge-triggered flip-flops, various shift registers, and synchronous /asynchronous counters with modulus control using HDL.

CO5: EVALUATE and compare different A/D and D/A conversion techniques based on their working principles, accuracy, resolution, and suitability for specific applications.

Course Contents

Unit I	Field Effect Transistors and Operational Amplifier	(08 Hours)

Field Effect Transistors: Junction Field Effect Transistors, MOSFETs, Differences between JFETs and MOSFETs, Biasing MOSFETs, FET applications, CMOS devices, Wave shaping circuits-Integrated Circuit (IC) multivibrators.

Introduction to Operational Amplifier: Ideal v/s practical Op-Amp, Performance parameters.

Operational Amplifier Application Circuits: Peak detector circuit, Comparator, Active filters, Non-linear amplifier, Relaxation oscillator, Current to voltage converter, Voltage to current converter.

Real World Assignment:

1. Build a practical peak detector and a comparator using an op-amp, then cascade them with an active low-pass filter to create a non-linear amplifier that triggers an alarm only when a signal's amplitude exceeds a threshold for a specific duration
2. Construct a relaxation oscillator using a 555 timer IC (as an IC multivibrator) and an op-amp integrator, then modify it into a voltage-to-current converter to drive an LED, measuring frequency stability against supply voltage changes.
3. Build a light/dark sensor using an Op-Amp comparator.

Exemplary: Smartphone battery charging circuits, Microprocessor memory chips, Line-follower sensors, Battery overcurrent protection in mobile robots, Robotic gripper force control, Obstacle detection using op-amp comparators.

Unit II	Basic Gates and Combinational Logic Circuits	(07 Hours)

Basic Gates: Review of basic logic gates, Positive and negative logic, Introduction to Hardware Description Language (HDL).

Combinational Logic Circuits: Sum of products method, Truth table to Karnaugh Map, Pairs Quads, and Octets, Karnaugh simplifications, Don't-care conditions, Product of sums method, Product of sums simplifications, Simplification by Quine McClusky method, Hazards and hazard covers, HDL implementation models.

Real World Assignment:

1. Design a 4-bit binary-to-BCD converter using Karnaugh map simplification and implement it in Verilog HDL, then verify its functionality for decimal display on a 7-segment LED.
2. Implement a digital alarm system using Product of Sums simplification for a 3-input majority voter circuit, then compare its gate-level HDL model with a behavioral model for timing and area.
3. Minimize a 5-variable logic function for a traffic light controller using the Quine-McCluskey method, identify and cover static-1 hazards, and simulate the hazard-free circuit using HDL testbenches.

Exemplary: ALU control logic in microprocessors, Emergency stop circuit, Encoder decoding, Sensor arbitration, Motor direction logic, FPGA motor control, Digital thermometer sensor interfacing.

Unit III	Data Processing Circuits and Flip-Flops	(07 Hours)

Data-Processing Circuits: Multiplexers, Demultiplexers, 1-of-16 Decoder, Binary coded decimal (BCD) to decimal decoders, Seven segment decoders, Encoders, Exclusive-OR Gates, Parity generators and checkers, Magnitude comparator, Programmable array logic, Programmable logic arrays, HDL implementation of data processing circuits. Arithmetic building blocks, Arithmetic logic unit.

Flip- Flops: RS flip-flops, Gated flip-flops, Edge triggered RS flip-flop, Edge triggered D flip-flops, Edge triggered JK flip-flops.

Real World Assignment:

1. Design a 4:1 multiplexer-based 7-segment display controller for a digital calculator, implement it using HDL, and verify BCD-to-decimal decoding for all digits.
2. Build a 4-bit magnitude comparator using HDL to compare two sensor values in a robotic obstacle avoidance system, and test it with edge-triggered D flip-flops for latching the comparison result.
3. Implement an 8-bit ALU (Arithmetic Logic Unit) with addition, subtraction, AND, OR, and XOR operations using programmable logic array (PLA), and simulate it with JK flip-flops.

Exemplary: Error detection in data transmission, Robot arm calculations, Divide encoder pulses for wheel speed, Wireless command error detection, Programmable logic in automotive ECU, Telephone switching systems.

Unit IV	Flip-Flops, Registers, Counters	(07 Hours)

Flip-Flops: Flip-flop timing, JK master-slave flip-flop, Switch contact bounce circuits, Various Representation of flip-flops, HDL implementation of flip-flop.

Registers: Types of registers, Serial In - Serial Out, Serial In -Parallel out, Parallel In - Serial Out, Parallel In -Parallel Out, Universal shift register, Applications of shift registers, Register implementation in HDL.

Counters: Asynchronous counters, Decoding gates, Synchronous counters, Changing the counter modulus.

Real World Assignment:

1. Design a 4-bit universal shift register using D flip-flops in HDL to implement a serial-in-parallel-out (SIPO) data acquisition system for an SPI temperature sensor, and verify its operation.
2. Implement a synchronous BCD counter using JK master-slave flip-flops with a modulus change feature to create a programmable digital stopwatch that counts from 0 to 59 seconds.
3. Build a switch debounce circuit using an RS flip-flop to eliminate contact bounce in a push-button start mechanism for a conveyor belt motor, and simulate it using HDL testbenches.

Exemplary: Autonomous mobile robot wheel encoder odometry, Robotic arm joint angle control, Humanoid robot gait timing, Robot gripper force feedback, Drone flight controller ESC signal generation.

Unit V	Counters and A/D, D/A Convertors	(07 Hours)

Counters: Decade counters, Presettable counters, Counter design as a synthesis problem, A Digital clock, Counter design using HDL.

D/A Conversion and A/D Conversion: Variable, Resistor networks, Binary ladders, D/A Converters, D/A accuracy and resolution, A/D Converter-simultaneous conversion, A/D Converter-counter method, continuous A/D conversion, A/D techniques, Dual-slope A/D conversion, A/D accuracy and resolution.

Real World Assignment:

1. Design a 24-hour digital clock using decade counters and presettable counters with HDL, incorporating a 1 Hz clock derived from a 50 MHz crystal oscillator.
2. Implement a 4-bit successive approximation ADC using a counter method and a binary ladder D/A converter to digitize a potentiometer voltage for a robotic joystick input.
3. Build a dual-slope ADC using an op-amp integrator and digital counters to measure temperature from a thermistor with 0.1°C resolution, and verify its accuracy against a commercial multimeter.

Exemplary: Motor encoder position counting, Robot arm torque sensing, Line-follower analog sensor digitization, Mobile robot mapping, Swarm robot synchronization, Drone altitude sensor, LiDAR distance measurement.

Learning Resources

Text Books:

1. Mano, M. M., & Ciletti, M. D. (2018). *Digital design: With an introduction to the Verilog HDL, VHDL, and System Verilog (6th Ed.).* Pearson.
2. Millman, J., & Halkias, C. C (2018). *Integrated electronics: Analog and digital circuits*. McGraw Hill.
3. Salivahanan, S., & Suresh Kumar, N. (2022). *Electronic devices and circuits*. McGraw Hill.
4. Mano, M. M**.** (2003). *Digital design (3rd Ed.)*. Pearson Education.
5. Kohavi, Z., & Jha, N. K. (2012). *Switching and finite automata theory (3rd Ed.).* Cambridge University Press.

Reference Books:

1. Kishore, K. L. (2025). *Electronic devices and circuits*. B.S Publications.
2. Raju, G. S. N. (2006). *Electronic devices and circuits*. I.K. International Publications.
3. Wakerly, J. F. (2006). *Digital design (4th Ed.).* Pearson/Prentice Hall.
4. Yarbrough, J. M. (2002). *Digital logic applications and design*. Thomson Learning.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Analog Electronics Circuit
   https://nptel.ac.in/courses/108106188
2. NPTEL Course: Digital Electronics Circuit
   https://nptel.ac.in/courses/108105132
3. Coursera Course: Basic Electronics
   https://www.coursera.org/learn/basic-electronics-odc

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
PCC-204-RAI: Analog and Digital Electronics Lab				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	**NA**	**1**	**Oral**	**NA**
Practical	**2 Hours/Week**		**Practical**	**50 Marks**

Prerequisite:

Basic Electronics Engineering (ESC-101-ETC),
Basic Electrical Engineering (ESC-102-ELE)

Course Objectives:

The student will be able

1. To understand analog components and circuits including operational amplifier, timer and combinational logic circuits.
2. To understand flip - flops and their operations.
3. To understand counters and registers using flip-flops.
4. To understand knowledge of synchronous and asynchronous sequential circuits.
5. To understand knowledge of A/D and D/A converters.

Course Outcomes:

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

CO1: UNDERSTAND various electronic devices like cathode ray oscilloscope, signal generators, digital trainer kit, multimeters and components like resistors, capacitors, op-amp and integrated circuit.

CO2: CLASSIFY various combinational logic circuits.

CO3: ANALYZE various types of counters and registers using Flip-flops.

CO4: EVALUATE simulation package of design circuits.

CO5: APPLY and understand the working and implementation of Arithmetic Logic Unit (ALU).

Laboratory Experiments/Assignments	
The student must complete the following activity for their Term Work Journal (Any 8 Experiments)	
Practical 1	a) Design and construct a Schmitt trigger using Op-Amp for given UTP and LTP values and demonstrate its working. b) Design and implement a Schmitt trigger using Op-Amp using a simulation package for two sets of UTP and LTP values and demonstrate its working.
Practical 2	a) Design and construct a rectangular waveform generator (Op-Amp relaxation oscillator) for given frequency and demonstrate its working. b) Design and implement a rectangular waveform generator (Op-Amp relaxation oscillator) using a simulation package and demonstrate the change in frequency when all resistor values are doubled.
Practical 3	Design and implement an as table multivibrator circuit using 555 timers for a given frequency and duty cycle.
Practical 4	Design and implement Half adder, Full Adder, Half Subtractor, Full Subtractor using basic gates.
Practical 5	a) Given a 4-variable logic expression, simplify it using Entered Variable Map and realize the simplified logic expression using 8:1 multiplexer IC. b) Design and develop the Verilog /VHDL code for an 8:1 multiplexer. Simulate and verify it's working.
Practical 6	Design and implement code converter I) Binary to Gray (II) Gray to Binary Code using basic gates.
Practical 7	Design and verify the Truth Table of 3-bit Parity Generator and 4-bit Parity Checker using basic Logic Gates with an even parity bit.
Practical 8	a) Realize a J-K Master / Slave Flip-Flop using NAND gates and verify its truth table. b) Design and develop the Verilog / VHDL code for D Flip-Flop with positive edge triggering. Simulate and verify it's working.
Practical 9	a) Design and implement a mod-n (n< 8) synchronous up counter using J-K Flip- Flop ICs and demonstrate its working. b) Design and develop the Verilog / VHDL code for mod-8 up counter. Simulate and verify it's working.
Practical 10	Design and implement an asynchronous counter using decade counter IC to count up from 0 to n (n<=9) and demonstrate on 7-segment display (using IC- 7447).
Practical 11	Generate a Ramp output waveform using DAC0800 (Inputs are given to DAC through IC74393 dual 4-bit binary counter).
Practical 12	To study 4-bitALU using IC-74181.

Learning Resources

Text Books:

1. Mano, M. M., & Ciletti, M. D. (2018). *Digital design: With an introduction to the Verilog HDL, VHDL, and SystemVerilog (6th Ed.)*. Pearson.
2. Millman, J., & Halkias, C. C (2018). *Integrated electronics: Analog and digital circuits*. McGraw Hill.
3. Salivahanan, S., & Suresh Kumar, N. (2022). *Electronic devices and circuits*. McGraw Hill.

Reference Books:

1. Kishore, K. L. (2025). *Electronic devices and circuits*. B.S Publications.
2. Raju, G. S. N. (2006). *Electronic devices and circuits*. I.K. International Publications.
3. Wakerly, J. F. (2006). *Digital design (4th Ed.)*. Pearson/Prentice Hall.
4. Yarbrough, J. M. (2002). *Digital logic applications and design*. Thomson Learning.

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1. NPTEL Course: Analog Electronics Circuit
   https://nptel.ac.in/courses/108106188
2. NPTEL Course: Digital Electronics Circuit
   https://nptel.ac.in/courses/108105132
3. Coursera Course: Basic Electronics
   https://www.coursera.org/learn/basic-electronics-odc

Real World Assignment:

1. Design a noise-immune door safety sensor for industrial elevators using a Schmitt trigger (UTP/LTP = ±2V) to prevent false triggers from vibration.
2. Build a programmable LED flasher (1–10Hz) for emergency vehicles. Double resistors in simulation and analyze frequency stability.
3. Create a soil moisture monitor that beep at 2Hz (dry soil) or 0.5Hz (wet soil) using a 555 timer.
4. Implement a vending machine "coin adder" using full adders to sum coins (binary inputs) and trigger a product release.
5. Simplify a 4-variable industrial alarm system (smoke, temp, door, motion) using an 8:1 MUX (IC 74151). Write VHDL code for FPGA deployment.
6. Design a robotic arm position encoder that converts Gray code (from rotary encoders) to binary for a microcontroller.
7. Build a UART error detector for a weather station transmitting 3-bit temperature data with even parity.

8. Prototype a bank queue token system using JK flip-flops (IC 7476) to cycle through tokens 0–7. Write VHDL for a DFF-based upgrade.
9. Develop a traffic light sequencer (mod-6 counter) using JK flip-flops. Simulate a mod-8 Verilog counter for pedestrian crossings.
10. Create a digital fuel dispenser showing liters (0–9) on a 7-segment display using IC 7490.
11. Generate a variable-pitch alarm using a DAC0800 ramp fed by IC 74393. Correlate frequency to ramp slope.
12. Simulate a calculator core using IC 74181 to add/subtract 4-bit numbers. Extend to 8-bit in theory.

Exemplary: Switch debouncing in industrial push-buttons, PWM generation for DC motor speed control, Multiplexing multiple sensors to a single ADC, Servo motor pulse generation using 555 timer, Ultrasonic rangefinder echo signal conditioning.

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised					
MDM-221-RAI: Mathematics for Intelligent Systems					
Teaching Scheme		**Credit**	**Examination Scheme**		
Theory	**3 Hours/Week**	**3**	**CCE**	**40 Marks**	
Practical	**NA**		**End-Semester**	**60 Marks**	

Prerequisite:

Engineering Mathematics-I (BSC-101-BES),
Engineering Mathematics-II (BSC-151-BES)

Course Objectives:

The student will be able

1. To interpret statistical measures for quantitative data.
2. To analyze datasets using probability theory and linear algebra.
3. To compare the system's behavior for the experimental data.
4. To apply differential equations to solve the applications in the domain of statics & dynamics, etc.
5. To use numerical integration techniques for engineering applications.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: APPLY statistical methods in testing & quality control.

CO2: PERFORM vector differentiation & integration, and apply to fluid flow problems.

CO3: EVALUATE solution of algebraic equations and find surface areas, volumes using numerical techniques.

CO4: SOLVE higher order linear differential equations and its applications to model and analyze spring-mass system.

CO5: APPLY numerical techniques to solve initial and boundary value problems for various engineering applications.

Course Contents

Unit I	Statistics and Probability	(08 Hours)

Statistics: Introduction to data science, Population, Sample, Measures of central tendency, Measures of dispersion, Coefficient of variation, Moments, Skewness and kurtosis, Correlation analysis: Pearson's correlation.

Probability: Probability, Theorems on probability, Bayes theorem, Random variables, Mathematical expectation, Probability distributions: Binomial, Poisson, Normal, Test of hypothesis: T-Test, Z-Test, Chi-Square Test.

Real World Assignment:

1. Identify important probability and statistics theorems and methods that are commonly used for applications in engineering.
2. Solve basic probability and statistic problems for applications in engineering using concepts such as total probability, Bayes' rule, continuous and discrete distributions, etc.
3. To measure statistical features of experimental data/standard datasets from scientific websites.

Exemplary:

Machine learning application for training neural networks with gradient descent and linear regression for predictive analytics.

Unit II	Vector Calculus	(07 Hours)

Fundamentals of Vector Calculus: Vector differentiation, Gradient, divergence and curl, Directional derivative, Solenoidal & irrotational fields, Vector identities, Line integrals, Surface integrals and Volume integrals, Applications of Stoke's & Green's theorems.

Real World Assignment:

1. Electric field from distributed charge.
2. Plotting a Slice of a vector field.
3. To describe fluid flow, pressure distributions, and forces acting on objects immersed in fluids.

Exemplary:

Solving differential equations to analyze stress, strain, and load distribution in bridges, buildings, and dams. Calculating joint trajectories and inverse kinematics for robotic arms.

Unit III	Numerical Solution of Equations	(07 Hours)

Roots of Equation: Bisection method, Regula-False method, Newton-Raphson & Successive Approximation method.

Numerical Solutions of system of linear equations: Gauss elimination, LU decomposition, Cholesky Jacobi and Gauss seidel methods.

Real World Assignment:

Analytical solution for any one of the following applications:

1. Heat & mass balance equations.
2. Newton's laws of motion.
3. Force balance.

Exemplary:

Simulating airflow over aircraft wings or fluid flow in pipelines using Navier-Stokes equations. Designing PID controllers for robots, drones, and industrial automation using transfer functions.

Unit IV	Numerical Solution of Differential Equations and Integral	(07 Hours)

Solution of Ordinary Differential Equations: Taylor series method, Picard's Method, Euler method, Runge-Kutta method, Mille's predictor and corrector method.
Numerical Integration: Trapezoidal rule, Simpson's 1/3rd rule, Simpson's 3/8th rule.

Real World Assignment:

Analytical solution for any one of the following applications:
1. The swinging pendulum.
2. Heat conduction equation: A thin rod, insulated at all points except of the ends.
3. Analyze the unforced oscillations of an automobile shock absorber.

Exemplary:

Modeling heat dissipation in electronics or thermal efficiency in power plants, Analyzing RLC circuits with time-varying inputs.

Unit V	Finite Difference Methods	(07 Hours)

Finite Difference Method (FDM): Initial & boundary value problems, Formulation of forward, backward & central difference approximation, 1D ODE problem solutions using FDM.
Partial Differential Equations (PDE): Elliptical-Laplace & Poisson's equation, Parabolic & Hyperbolic equations and their engineering applications.

Real World Assignment:

Analytical solution using numerical methods for any one of the following applications:
1. A non-insulated uniform rod positioned between two bodies of constant but different temperatures.
2. Damped/Undamped spring-mass system.
3. Simulating transient current for an electric circuit.

Exemplary:

Simulating crash tests for cars or vibration analysis in machinery, Simulating airflow over aircraft wings, car designs (CFD- Computational Fluid Dynamics).

Learning Resources

Text Books:

1. Chapra, S. C. (2018). *Applied numerical methods with MATLAB for engineers and scientists (4th Ed.)*. McGraw-Hill Education.
2. Grewal, B. S. (2018). *Numerical methods in engineering and science (10th Ed.)*. Khanna Publishers.

3. Grewal, B. S. (2020). *Higher engineering mathematics (45th Ed.).* Khanna Publishers.
4. Gupta, S. P. (2019). *Statistical methods (5th Ed.)*. Sultan Chand & Sons.

Reference Books:

1. Hoffman, J. D. (2001). *Numerical methods for engineers and scientists (2nd Ed.).* CRC Press.
2. Kreyszig, E. (2011). *Advanced engineering mathematics (10th Ed.).* Wiley India.
3. Ross, S. M. (2014). *Introduction to probability and statistics for engineers and scientists (5th Ed.).* Elsevier Academic Press.
4. Schilling, R. J., & Harris, S. L. (2000). *Applied numerical methods for engineering using MATLAB and C*. Cengage Learning India Pvt. Ltd.
5. Deisenroth, M. P., Faisal, A. A., & Ong, C. S. (2020). *Mathematics for machine learning*. Cambridge University Press.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Engineering Mathematics
   https://nptel.ac.in/courses/111105121

2. NPTEL Course: Engineering Mathematics II
   https://nptel.ac.in/courses/111105134

3. Coursera Course: Mathematics for Engineering Specialization
   https://www.coursera.org/specializations/bits-mathematics-for-engineering-specialization

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
MDM-222-RAI: Computer Programming Lab				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	**NA**	**1**	**CCE**	**NA**
Practical	**2 Hours/Week**		**Practical**	**50 Marks**

Prerequisite:

Fundamentals of Programming Languages (ESC-105-COM),
Programming and Problem Solving (PCC-151-ITT)

Course Objectives:

The student will be able

1. To understand and apply programming fundamentals (variables, data types, operators, control flow, user input) in Python and C++.
2. To use collections (lists, tuples, sets, dicts in Python; arrays, strings, pointers in C++) effectively.
3. To implement modular programs using functions, lambda/overloading, recursion, and scope handling.
4. To Apply OOP concepts (classes, objects, inheritance, polymorphism, friend functions).
5. To Handle errors, file I/O, and use advanced features (modules/JSON in Python; templates/STL in C++).

Course Outcomes:

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

CO1: APPLY variables, data types, operators, control flow, and user input to write basic programs in Python and C++.

CO2: ANALYZE problems and select appropriate collections (lists, tuples, sets, dicts / arrays, strings, pointers) for data manipulation.

CO3: CREATE modular programs using functions, lambda/overloading, recursion, and scope management.

CO4: IMPLEMENT OOP concepts (classes, objects, inheritance, polymorphism, friend functions) to model real-world entities.

CO5: CONSTRUCT robust applications using exception handling, file handling, modules/JSON, and templates/STL.

Laboratory Experiments/Assignments	
The student must complete the following activity for their Term Work Journal	
Part A	**Python Programming**
Practical 1	Study and write programs for Variables, Data Types, Operators, and User Input.
Practical 2	Study and write programs for Control Flow (Conditional Statements and Loops).
Practical 3	Study and write programs for Lists, Tuples, Sets, and Dictionaries (Collections).
Practical 4	Study and write programs for Functions, Lambda, Scope, and Recursion.
Practical 5	Study and write programs for Classes, Objects, and Object-Oriented Programming (OOPs).
Practical 6	Study and write programs for Exception Handling, File Handling, Modules, and JSON.
Part B	**C++ Programming**
Practical 1	Study and write programs for Basics, Syntax, Variables, Data Types, Operators, and Control Flow.
Practical 2	Study and write programs for Arrays, Strings, Pointers, and References.
Practical 3	Study and write programs for Functions, Scope, Overloading, and Recursion.
Practical 4	Study and write programs for Structures, Enums, and Object-Oriented Programming.
Practical 5	Study and write programs for Inheritance, Polymorphism, and Friend Functions.
Practical 6	Study and write programs for Exception Handling, File Handling, Templates, and STL.

Learning Resources

Text Books:

1. Lippman, S. B., Lajoie, J., & Moo, B. E. (2012). *C++ primer (5th Ed.*). Addison-Wesley.
2. Stroustrup, B. (2024). *Programming: Principles and practice using C++ (3th Ed.).* Addison-Wesley.
3. Matthes, E. (2023). *Python crash course: A hands-on, project-based introduction to programming (3rd Ed.).* No Starch Press.
4. Guttag, J. V. (2021). *Introduction to computation and programming using Python: With application to computational modeling and understanding data (3rd Ed.).* MIT Press.
5. Gaddis, T. (2024). *Starting out with Python (6th Ed.).* Pearson.

Reference Books:

1. Josuttis, N. M. (2012). *The C++ standard library: A tutorial and reference (2nd Ed.).* Addison-Wesley Professional.
2. Stroustrup, B. (2013). *The C++ programming language (4th Ed.).* Addison-Wesley.
3. Beazley, D. M., & Jones, B. K. (2013). *Python cookbook (3rd Ed.).* O'Reilly Media.

4. Slatkin, B. (2019). *Effective Python: 90 specific ways to write better Python (2nd Ed.)*. Addison-Wesley.
5. Lutz, M. (2014). *Python pocket reference (5th Ed.).* O'Reilly Media.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Programming, Data Structures and Algorithms using Python
   https://nptel.ac.in/courses/106106145
2. NPTEL Course: Programming in Modern C++
   https://nptel.ac.in/courses/106105234
3. Coursera Course: Programming for Everybody (Getting started with Python)
   https://www.coursera.org/learn/python

Real World Assignments:

1. Write a Python program that takes a customer's purchase amount and discount percentage as input, calculates the final price using arithmetic operators, and displays it with appropriate data types.
2. Write a Python program that prints all numbers from 1 to 100, but for multiples of 3 print "Fizz", for multiples of 5 print "Buzz", and for multiples of both print "Fizz Buzz".
3. Write a Python program that takes a sentence from the user, stores unique words in a set, word lengths in a list, and word-frequency in a dictionary.
4. Write a Python program with a recursive function to calculate Fibonacci series, a lambda to check if a number is even, and demonstrate local vs. global variable scope.
5. Write a Python program with a Bank Account class having attributes account number, holder name, balance, and methods to deposit, withdraw, and display balance; create two objects.
6. Write a C++ program that takes two numbers and an operator (+, -, *, /) from user input and performs the calculation using if-else or switch.
7. Write a C++ program that takes 5 strings as input into an array, uses a pointer to traverse and reverse each string, and prints the result using references.
8. Write a C++ program with overloaded functions to calculate area (circle, rectangle, triangle), a recursive function to find GCD, and demonstrate global vs local scope.
9. Write a C++ program defining a student struct (name, roll, marks), an enum for grades (A, B, C, D, F), and a class Classroom with methods to add and display students.
10. Write a C++ program with a base class Shape, derived classes Circle and Rectangle, a virtual function area (), and a friend function to compare areas of two shapes.
11. Write a C++ program that reads integers from a file, uses a template function to find maximum, handles division by zero exception, and stores sorted results using STL vector.

Exemplary: ROS (Robot Operating System) nodes for prototyping, Machine learning for autonomous navigation, Speech recognition and natural language processing, Real-time motor control and PID algorithms, Sensor fusion (Kalman filters, IMU processing), High-frequency trajectory generation and control loops.

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
VSEC-231-RAI: Computer Aided Design Lab				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	**NA**	**1**	**Term work**	**NA**
Practical	**2 Hours/Week**		**Practical**	**25 Marks**

Prerequisite:
Engineering Graphics (ESE-103-MEC),
Engineering Mathematics - I and II (BSC-101-BES, BSC-151-BES)

Course Objectives:

The student will be able

1. To introduce the fundamentals of 2D sketching with geometric and dimensional constraints for precise technical drawings.
2. To develop skills in solid and surface modeling techniques for various mechanical components, including sheet metal, castings, forgings, and plastic-molded parts.
3. To train in assembly modeling using appropriate constraints and generating exploded views for better visualization of mechanical assemblies.
4. To familiarize with Product Manufacturing Information (PMI) and Model-Based Definition (MBD) for efficient design communication and manufacturing.
5. To demonstrate CAD customization techniques (scripting/macros) to enhance productivity in product development.

Course Outcomes:

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

CO1: CREATE 2-D sketching with geometrical and dimensional constraints.

CO2: CONSTRUCT solid and surface modeling of mechanical components (Sheet metal, Casting, Forgings, Plastic molding).

CO3: ASSEMBLE different part models of (Sheet metal, Casting, Forging, Plastic molding) with using proper assembly constraint conditions and generation of exploded view for assemblies.

CO4: USE PMI & MBD approach for communication and customization.

CO5: APPLY CAD customization in product development.

Laboratory Experiments/Assignments

The student shall complete the following activity as a Term Work Journal.

Practical 1	**2-D sketching with geometrical and dimensional constraints** 1. Creating 2D sketches of machine parts using its Front, top, and side views. 2. Dimensioning and annotations. 3. Creating isometric drawings from orthographic views.
Practical 2	**Solid modeling for simple mechanical components** 1. Sketch-based modeling (extrude, revolve, sweep, loft). 2. Applying constraints (geometric and dimensional). 3. Parametric modeling, analytical modeling etc.
Practical 3	**Surface and Sheet metal modeling for simple mechanical components** 1. Creating surface models using patch, loft, and sweep, etc. 2. Converting surfaces into solid. 3. Sheet metal features: flange, bend, hem, etc.
Practical 4	**Assembly modeling** 1. Inserting components into an assembly. 2. Applying mates and constraints. 3. Assembly motion and interference checking.
Practical 5	**Production drawing and Model Based Definition (MBD) of Part and Assembly** 1. Creating 2D drawing views from 3D parts. 2. Exploded views and Bill of Materials (BOM). 3. Adding GD&T symbols. 4. Production Drawing with MBD.
Practical 6	**Demonstration on CAD Customization (with introduction to programming languages, interfacing)** 1. Auto-generate a grid of holes in a plate using Python. 2. Write a script that draws parametric windows (change height/width with variables). 3. Automate layer creation and object coloring in CAD software.

Learning Resources

Text Books:

1. Zeid, I., & Sivasubramania, R. (2009). *CAD/CAM: Theory and practice* (*2nd Ed.*). McGraw Hill Education.
2. Rao, P. N. (2017). *CAD/CAM principles and applications*. Tata McGraw Hill Publishing Company Ltd.
3. Tickoo, S. (2014). *CATIA V5 for designers*. CADCIM Technologies.
4. Shaikh, M. M. M. (2012). *CATIA V5 for engineers*. Laxmi Publications.

Reference Books:

1. Ambrosius, L. (2015). *AutoCAD® platform customization: User interface, AutoLISP®, VBA, and beyond*. John Wiley & Sons, Inc.
2. Reddy, J. N., & Sekhar, C. (2011). *CATIA V5: Macro programming with VBA*. Springer.
3. Cozzens, R. (2006). *Advanced CATIA V5 workbook.* SDC Publications
4. Ascent (2018). *CATIA V5-6r2017: Introduction to Modeling*. Center for Technical Knowledge.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: CAD/CAM
   https://onlinecourses.swayam2.ac.in/e-learning/preview/nou22_me08

2. NPTEL Course: Computer Aided Design and Manufacturing
   https://nptel.ac.in/courses/112102101

3. Coursera Course: Introduction to 3D Modeling
   https://www.coursera.org/learn/introduction-to-3d-modeling

Real World Assignment:

1. Select a simple robot part (gripper finger, base plate, or link), sketch its front/top/side views with dimensions.
2. Measure a physical robot component (bracket, motor mount), create its orthographic 2D sketches with proper annotations, and compare with standard engineering drawing conventions.
3. Model a simple gripper finger or suction cup mount using extrude/revolve/sweep features, applying geometric constraints and parametric dimensions for adjustable grip width.
4. Create a parametric model of a robotic arm link where changing length/width automatically updates the entire part, simulating design iterations for different robot configurations.
5. Design a robot chassis or enclosure using sheet metal features (flange, bend, and hem), create flat patterns, and export DXF for laser cutting fabrication.
6. Assemble a 5-axis robot model with mates/constraints, run motion studies to simulate pick-and-place operations, and check for interferences.
7. Generate 2D drawings from your 3D robot assembly with exploded views, BOM, and GD&T (geometric dimensioning & tolerancing) suitable for shop-floor fabrication.
8. Write a Python script to auto-generate a grid of mounting holes on a robot base plate, with adjustable spacing and diameter variables.
9. Develop a script that creates parametric features (e.g., sensor mounting slots or cable routing cutouts) that update when key dimensions change.
10. Design a printable part, apply tolerances, and prepare it for 3D printing (export STL, add supports, etc.).

Exemplary:

1. Reverse engineer a physical robot link from an ABB or KUKA arm, measure dimensions using calipers, and create fully dimensioned 2D production sketches.
2. Model a robotic arm link (like those used in FANUC robots) using extrude and revolve features with parametric dimensions for adjustable reach.
3. Develop a fully annotated 3D model with PMI (Product Manufacturing Information) for a robot base plate used in Tesla's factory, enabling paperless manufacturing.
4. Create a script that automatically generates customizable end-effector adapters (ISO 9409-1 standards) for different robot brands (KUKA, ABB, FANUC) based on input parameters.

Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised

HSSM-232-RAI: Entrepreneurship Development and Innovation

Teaching Scheme		Credit	Examination Scheme	
Theory	**1 Hour/Week**	**1**	**CCE**	**25 Marks**
Practical	**NA**		**End-Semester**	**NA**

Prerequisite:

Design Thinking and Idea Lab (VSE-102)

Course Objectives:

The students will be able

1. To introduce the fundamentals of entrepreneurship, innovation, and entrepreneurial mindset for identifying business opportunities.
2. To understand the process of opportunity recognition, market research, and business model development using structured tools.
3. To explore startup planning, financial literacy, funding sources, and business feasibility analysis.
4. To develop entrepreneurial skills through design thinking, teamwork, business planning, and startup pitching.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: UNDERSTAND the concepts of entrepreneurship, innovation, opportunity identification, and business model development for creating sustainable ventures.

CO2: APPLY design thinking, business planning, financial analysis, and entrepreneurial strategies to develop and evaluate startup ideas.

Course Contents

Unit I	Entrepreneurial Mindset, Creativity and Innovation	(08 Hours)

- Entrepreneurial mindset: curiosity, resilience, risk-taking, leadership
- Types of entrepreneurs – Technical, Non-technical, Social, Entrepreneur
- Innovation types: product, service, process, frugal (Jugaad) innovation
- Design Thinking: Empathize, Define, Ideate, Prototype, Test
- Creativity tools: Mind Mapping, SCAMPER, TRIZ
- Success stories from Indian innovators
- Case studies: Innovative Indian products/startups

Assignments and Exercises (Any Three, Community Engagement Project is compulsory)

1. **Guest Session + Reflection Report**
   Application: Invite an Indian entrepreneur (e.g., local startup founder or alumni) for a guest talk.
   Task: Students write a 1-page reflection/ Quiz on entrepreneurial mindset, risks taken, and innovation style.

2. **Case Study Presentation**
   Activity: Select an Indian start up and analyze:
   - The problem it solves
   - Type of innovation (product, process, frugal, etc.)
   - Entrepreneurial mindset of the founder

   Deliverable: Present as a 5-minute video or a PPT with voice narration.

3. **Present any one Course Project/ Community Engagement Project (CEP) in context with Design Thinking**
   Activity: In small groups, students will solve a common college problem (e.g., canteen cleanliness, Wi-Fi issues, exam stress, long queues, absenteeism, lack of seating, etc.) using the Design Thinking process in 45–60 minutes:
   a. Empathize (5–10 min): Talk to 2–3 students or staff to understand the issue
   b. Define (5 min): Clearly write the problem in one sentence
   c. Ideate (10–15 min): Brainstorm at least 5–7 possible solutions
   d. Prototype (10–15 min): Create a quick sketch, model, or chart of the best solution
   e. Test (10 min): Share the idea with another group and collect feedback
   Deliverable: Student should present 1 page summary/ poster/ prototype of the Course Project / Community Engagement Project (CEP) in context with Design Thinking

4. **Campus Creativity Challenge**
   Application:
   - Use **Mind Mapping** to improve a college service (e.g., library hours, parking space).
   - Apply **SCAMPER** to redesign a student-used item (e.g., backpack, ID card).
   - Use **TRIZ** to resolve a contradiction (e.g., "How to make exams easy but still effective").
   - Use **Design Thinking** process to solve college problem (e.g., canteen cleanliness, Wi-Fi issues, exam stress, long queues, absenteeism, lack of seating, etc)

   Deliverable: Student should present 1 page summary/ poster/ prototype of the Course Project in context with Design Thinking.

Exemplars / Practical Applications: Problem solving in Startups

Unit II	Opportunity Identification and Business Modelling	(08 Hours)

- Opportunity Recognition and Idea Generation - Problem identification and need analysis
- Market research: tools and techniques
- Business Model Canvas: customer segments, value proposition, channels
- Lean Startup methodology & Minimum Viable Product (MVP)

- Business plan components and structure
- Cost estimation, revenue models, and unit economics
- Funding options: Government schemes (Startup India, MSME), VC, Angel Investors,
- Crowd funding
- Basics of financial literacy: Profit-Loss, Break-even, cash flow.

Assignments and Exercises *(Any Three)*

1. **Conduct Startup Financials Workshop**
   Application: Hands-on session using a fictional startup (e.g., chai café):
   - Calculate fixed and variable costs
   - Identify breakeven point
   - Build a simple cash flow chart for 6 months

   Outcome: Submit an Excel sheet with key financial metrics and a one-page interpretation.

2. **Government Funding Scheme Research**
   Application:
   - Each group explores one government scheme (e.g., Startup India Seed Fund, MUDRA loan, PMEG Scheme, MSME credit)
   - Analyze eligibility, application process, benefits, and success stories

3. **Opportunity Recognition and Need Analysis**
   Activity: Identify 3 real-life problems a community face (e.g., water waste, long queues, and costly transportation) or college.
   - Conduct informal interviews or surveys to understand the need.
   - Analyze user pain points and existing gaps.
   - Select one high-potential problem and formulate an idea to solve it.

   Deliverable: Opportunity report with problem statement, user quotes, and proposed idea.

4. **Business Model Canvas + MVP Design**
   Activity: Choose a startup idea and:
   - Create a detailed **Business Model Canvas** (cover all 9 blocks).
   - Develop a basic **Minimum Viable Product (MVP)** – this could be a sketch, clickable prototype, or service flow.

   Deliverable: BMC template filled + MVP mock-up/photo.

5. **Business Plan + Funding Strategy + Pitch**
   Activity: Prepare a **business plan** including:
   - Executive summary
   - Product/service details
   - Market research insights
   - Costing and basic unit economics
   - Revenue model
   - Funding plan (choose and justify one: govt scheme, VC, angel, crowd funding)

- Prepare elevator pitch / 1 minute pitch

Deliverable: 4–6-page business plan document + pitch deck (5–7 slides).

Outcome: Awareness of the Government startup funding schemes and prepare a report of 3 to 4 pages.

Exemplars / Practical Applications: Arranging Mock Pitching Competitions

Learning Resources

Text Books:

1. Reddy, P. N. (2010). *Entrepreneurship: Text & cases*. Cengage Learning India.
2. Kuratko, D. F., & Rao, T. V. (2012). *Entrepreneurship: A South Asian perspective*. Cengage Learning India.
3. Leach, J. C., & Melicher, R. W. (2023). *Entrepreneurial finance*. Cengage Learning India.
4. Sundar, K. (2022). *Entrepreneurship development*. Vijay Nicole Imprints Private Limited.
5. Khanka, S. S. (2001). *Entrepreneurial development*. S. Chand & Co. Ltd.
6. Charantimath, P. M. (2018). *Entrepreneurship development and small business enterprises.* Pearson publishing
7. Nandan, H. (2011). *Essentials of entrepreneurship and small business management.* PHI Learning Publisher.

Reference Books:

1. Barringer, B. R. (2011). *Entrepreneurship: Successfully launching new ventures (3rd Ed.)*. Pearson.
2. Bessant, J., & Tidd, J. (2011). *Innovation and entrepreneurship (2nd Ed.)*. John Wiley & Sons.
3. Desai, V. (2011). *Small scale industries and entrepreneurship*. Himalaya Publishing House.
4. Kuratko, D. F. (2014). *Entrepreneurship: Theory, process and practice (9th Ed.)*. Cengage Learning.
5. Ries, E. (2011). *The lean startup*. Crown publisher.
6. Drucker, P. F. (2014). *Innovation and entrepreneurship*. Taylor & Francis Publisher.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Entrepreneurship
   https://nptel.ac.in/courses/110106141

2. NPTEL Course: Understanding Incubation and Entrepreneurship
   https://nptel.ac.in/courses/107101092

3. Coursera Course: Entrepreneurship Specialization
   https://www.coursera.org/specializations/wharton-entrepreneurship

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
VEC-233-RAI: Sustainable Development				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**2 Hours/Week**	**2**	**CCE**	**20 Marks**
Practical	**NA**		**End-Semester**	**30 Marks**

Prerequisite:

Design Thinking and Idea Lab (VSE-102)

Course Objectives:

The students will be able

1. To understand holistic and critical perspective on sustainability.
2. To provide with clear understanding of social development and sustainability.
3. To educate the students to think practically and strategically about sustainable habitat.
4. To apply frameworks such as the United Nations Sustainable Development Goals (SDGs) to assess and propose solutions for real-world sustainability issues.
5. To analyze case studies of sustainable and unsustainable practices to evaluate their long-term impacts on ecosystems and communities.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: **DESCRIBE** various concepts of social work, sustainability and SDGs.

CO2: **INFER** the sense of responsibility in addressing sustainable goals in developing a better society.

CO3: **DISCUSS** the policies and programs for achieving sustainable habitat.

CO4: **EVALUATE** the factors that influence the sustainable society, design, develop the policies to achieve SDGs.

CO5: **DESIGN**, develop and implement programs and policies for the better world.

Course Contents		
Unit I	**Fundamentals of Sustainability**	**(06 Hours)**
Basics of Sustainability: Concept and context of sustainability - Definition, Brief history, Sustainable development in India. **Pillars of Sustainability:** Social, Economic, Environmental, Cultural, Political, Security aspects. **Theories in Sustainability:** Social capital theory and mobilization, Bottom of the pyramid approach, Humanistic sustainability theory, Social economy theory.		
Real World Assignment: 1. Research real-world sustainable projects in India (e.g. Solar Power in Rajasthan, Zero-Budget Natural Farming in Andhra Pradesh, or Surat's Smart City Project). 2. Identify the environmental, economic, and social impacts of above listed projects. 3. Present findings in a report or infographic for any sustainable project in India.		
Exemplary: Sustainable agriculture case study, Water conservation report.		
Unit II	**Sustainable Habitat and Sustainable Energy**	**(06 Hours)**
Sustainable Habitat: Green buildings, Green materials, Energy efficiency, Sustainable transports. **Sustainable Energy:** Non-conventional sources, Energy cycles- carbon cycle, Emission and sequestration.		
Real World Assignment: 1. Calculation of carbon foot print. 2. Indian government policies for sustainable development projects. 3. Create posters, handouts, videos, or social media content to promote energy-saving habits in school/Institutes.		
Exemplary: Energy efficient buildings, Plastic-free campaign.		
Unit III	**Sustainable Developmental Goals (SDG 1-8)**	**(06 Hours)**
Sustainable Goals: Goal 1: No poverty, Goal 2: Zero hunger, Goal 3: Good health and wellbeing, Goal 4: Quality education, Goal 5: Gender equality, Goal 6: Clean water and sanitation, Goal 7: Affordable and clean energy, Goal 8: Decent work and economic growth.		
Real World Assignment: 1. Survey classmates about their daily diet and analyze if they're meeting nutritional requirements and propose low-cost nutritious meals. 2. Design a low-cost product/service for Bottom of the Pyramid (BoP) communities (e.g., solar lanterns for rural India). 3. Analyze India's progress on any one SDG and present findings in the form of a report.		
Exemplary: Model village for water conservation- Hiware Bazar, Solar powered Cochin international airport.		
Unit IV	**Sustainable Developmental Goals (SDG 9-17)**	**(06 Hours)**
Sustainable Goals: Goal 9: Industry, innovation, and infrastructure, Goal 10: Reduced inequality, Goal 11: Sustainable cities and communities, Goal 12: Responsible consumption and production, Goal 13: Climate action, Goal 14: Life below water, Goal 15: Life on land, Goal 16: Peace and justice strong institutions, Goal 17: Partnerships to achieve the goal.		

Real World Assignment:

1. Create posters, videos, or social media content to raise awareness about the 17 SDGs in your institute.
2. Design a product or art project using waste materials (plastic bottles, paper, cloth). Present how it promotes sustainability.
3. Research two countries' progress on a specific SDG and compare strategies. Prepare and present it in infographics highlighting successes and gaps.

Exemplary: Thanal- zero waste model, Toilets for all- Swachh Bharat Abhiyan, e-Choupal by ITC- Empowering farmers digitally.

Learning Resources

Text Books:

1. Kaltenborn, M., Krajewski, M., & Kuhn, H. (2020). *Sustainable Development Goals and human rights*. Springer Nature.
2. Lintsen, H., Veraart, F., Smits, J. P., & Grin, J. (2018). *Well-being, sustainability and social development: The Netherlands*, 1850–2050. Springer Nature.
3. Leal Filho, W., Tortato, U., & Frankenberger, F. (2021). *Integrating social responsibility and sustainable development: Addressing challenges and creating opportunities*. Springer publication.
4. Dayal, M. (1991). *Renewable energy; environment and development*. Konark Publishers Pvt. Ltd.

Reference Books:

1. Aliber, M. (2002). *Poverty-eradication and sustainable development*. HSRC Press.
2. Anders, B., & Roy, K. (2020). *Indigenous knowledges and the sustainable development agenda*. Taylor & Francis.
3. Rao, B. N. (2019). *Sustainable good governance, development and democracy*. Sage Publications.
4. Dessler, A. (2015). *Introduction to modern climate change (2nd Ed.)*. Cambridge University Press.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Education for Sustainable Development
   https://nptel.ac.in/courses/109105190
2. NPTEL Course: United Nations Sustainable Development Goals (UN SDGs)
   https://nptel.ac.in/courses/109106200
3. Coursera Course: The Age of Sustainable Development
   https://www.coursera.org/learn/sustainable-development

Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised

CEP-241-RAI: Community Engagement Project

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**2**	**Term Work**	**50 Marks**
Practical	**4 Hours/Week**		**Oral**	**NA**

Prerequisite:

Students should have prior knowledge of
1. Basic understanding of social and ethical responsibilities
2. Teamwork and communication skills acquired in prior course work or group activities
3. Familiarity with problem-solving methodologies and project planning
4. Conversation in local language

Companion Course:

1. CEP is an experiential learning approach that combines education, learning, community development, and meaningful community service.
2. Project involves students in community development and service activities and applies the experience to personal and academic development.
3. The targeted contribution of college students to the village/local development will benefit the community.
4. The college has an opportunity to help students become more socially conscious and responsible while simultaneously becoming a socially conscious organization.

Course Objectives:

The student will be able

1. Establish a mutually beneficial relationship between the college and the community.
2. Opportunities to engage with their local community, fostering empathy, teamwork, and problem-solving skills while contributing positively to their surroundings.
3. An understanding of the challenges faced by the local community and the role of engineering in addressing those challenges.
4. The ability to apply technical knowledge and skills to design solutions or interventions that create a positive impact on the community.
5. The skills to evaluate and critically analyze the outcomes of their engagement activities, deriving actionable insights for sustainable impact.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: IDENTIFY and **ANALYZE** local community needs and challenges by engaging with stakeholders and evaluating real-world problems.

CO2: DESIGN and **IMPLEMENT** practical, creative, and context-specific solutions using engineering principles to address community issues.

CO3: REFLECT and **EVALUATE** the effectiveness of their interventions and articulate lessons learned through reports and presentations.

Course Guidelines

Implementation

1. A group of 3 to 4 students or a single student could be assigned for a particular habitation or village or municipal ward, as far as possible, in the near vicinity of their place of stay/college premise.
2. Each group is allotted to a faculty member of the department as a mentor.
3. The group of students will be associated with a government official / village authorities /NGOs etc. concerned, allotted by the district administration, during the duration of the project.
4. The Community Engagement Project should be different from the regular programmes of NSS/NCC/Green Club/Hobby Clubs, Special Interests Groups etc.
5. An activity book has to be maintained by each of the students to record the activities undertaken/involved and will be countersigned by the concerned mentor/HoD.
6. Project report shall be submitted by each student/group of students.
7. An internal evaluation shall also be conducted by a committee constituted by the HoD. Evaluation to be done based on the active participation of the student and marks could be awarded by the mentor/HoD.
8. Students groups can conduct an awareness programme on Health and Hygiene or in Organic Farming or in Fisheries or in advocating prohibition of liquor or about renewable energy, e-waste management or any other activity in an area of their studies and as per his/her aptitude.

Suggestive list of topics under Community Engagement Project

The below lists are not exhaustive and open for HoD or mentors to add, delete or modify. It is expected that the focus should be on specific local issues in their nearby areas. The students are expected to carry out these projects with involvement, commitment, responsibility and accountability. The mentors of a student/group of students shall:

1. Agricultural Automation
2. Healthcare
3. Smart Cities
4. Sustainability & Environment

5. Public Safety & Infrastructure
6. Climate & Energy
7. Biodiversity & Ecosystems
8. Circular Economy & Waste
9. Water & Pollution
10. Social Equity & Adaptation
11. Policy & Innovation
12. Plantation and Soil protection
13. Renewable energy and Solar Systems
14. Organic farming
15. Incidence of Diabetes and other chronic diseases
16. Music and dance
17. Yoga awareness and practice
18. Women education and empowerment

Project Scope

1. Conduct workshops or awareness drives on topics like digital literacy, environmental sustainability, mental health, or career planning for local stakeholders.
2. Develop a simple prototype or solution that addresses a real-world problem (e.g., a water-saving device, simple mobile apps, or tools for community use).
3. Organize clean-up drives, tree plantations, recycling campaigns, or energy conservation initiatives.
4. Promote health through awareness programs on hygiene, nutrition, and exercise.
5. Teach basic computer or technical skills to students, staff, or the community.

Proposal Submission

CEP Group should Submit a two-page project proposal, preferably prior to the term commencement outlining the following:

- Title of the project
- Aim, Objective and expected outcome
- Plan of execution (timeline and activities).
- Place of the CEP and involvement of any local authority, NGP
- Required resources (if any).
- Get approval from the designated faculty mentor.

Learning Resources

Text Books:

1. Waterman, A. (1997). *Service-Learning: A guide to planning, implementing, and assessing student projects*. Routledge.
2. Beckman, M., & Long, J. F. (2016). *Community-based research: Teaching for community impact*. Stylus Publishing.
3. Brown T. (2015). *Design Thinking for Social Innovation.* IDEO Press.
4. Dostilio, L. D., et al. (2017). *The community engagement professional's guidebook: A companion to the community engagement professional in higher education*. Stylus Publishing.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Ecology and Society
   https://onlinecourses.nptel.ac.in/noc20_hs77/preview

Web Links:

1. UNESCO: Education for Sustainable Development https://www.unesco.org
2. EPICS (Engineering Projects in Community Service) https://engineering.purdue.edu/EPICS
3. Ashoka: Innovators for the Public https://www.ashoka.org
4. Design for Change https://www.dfcworld.com

Savitribai Phule Pune University, Pune

Maharashtra, India

SE - Robotics and Artificial Intelligence (2024 Pattern) Revised

Semester IV Courses

<table>
<tr><th colspan="5">Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised</th></tr>
<tr><th colspan="5">PCC-251-RAI: Sensors for Industrial Robotics</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th>Credit</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>Theory</td><td>3 Hours/Week</td><td rowspan="2">3</td><td>CCE</td><td>40 Marks</td></tr>
<tr><td>Practical</td><td>NA</td><td>End-Semester</td><td>60 Marks</td></tr>
</table>

Prerequisite:

Basic Electronics Engineering (ESC-101-ETC)

Course Objectives:

The student will be able

1. To introduce the fundamental concepts of industrial robotics and sensor technologies.
2. To provide a comprehensive understanding of position and proximity sensors.
3. To explore machine vision systems, including different camera types.
4. To understand the operation and applications of force and tactile sensors in robotics.
5. To examine advanced sensor systems in industrial robotics, including the integration of IoT.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: UNDERSTAND the essential role of sensors in robotic systems and identify different types of sensors (proximity, force, vision, tactile) used in industrial robotics.

CO2: IDENTIFY the position and proximity sensors in robots.

CO3: ANALYZE various types of vision sensors and implement basic image processing techniques.

CO4: CLASSIFY the different types of force and tactile sensors in robotic applications.

CO5: APPLY the role of sensor networks in industrial robotics, including IoT integration and wireless communication protocols for large-scale robot fleets.

Course Contents		
Unit I	**Introduction to Industrial Robotics and Sensors**	**(08 Hours)**

Introduction to Industrial Robotics: Definition and classification of robots, Applications of industrial robots.

Basics of Sensors in Robotics: Role of sensors in robotics, Types of sensors used in robotics-proximity, force, vision, tactile, etc.

Sensor Integration with Robots: Sensor interfaces and signal processing, Sensor fusion concepts, Sensor feedback systems in control loops.

Real World Assignment:

1. Design a sensor interface system for a pick-and-place robot integrating vision and proximity sensors, including signal conditioning and processing steps for reliable object detection and positioning.
2. Develop a sensor fusion strategy combining force and vision sensor data for closed-loop feedback control in a robotic assembly task, ensuring precise part insertion and defect prevention.

Exemplary: Automotive assembly line welding, Bin picking for machine tending, Electronic component insertion (PCB assembly), Automated palletizing & depalletizing, Aerospace composite layup, Collaborative robot (cobot) polishing, Food processing & packaging, and AGV navigation in warehouses.

Unit II	**Position and Proximity Sensors**	**(07 Hours)**

Position Sensors: Rotary encoders and linear encoders, Potentiometers and resolvers, Applications in robotic arms and mobile robots.

Proximity Sensors: Capacitive, inductive, and ultrasonic proximity sensors, Applications in proximity detection, collision avoidance, and robot localization.

Calibration of Position and Proximity Sensors: Importance of accurate calibration, Methods of calibration and alignment.

Real World Assignment:

1. Implement wheel odometry using linear encoders to track a robot's displacement.
2. Design a proximity sensing system using capacitive, inductive, and ultrasonic sensors for an autonomous mobile robot, ensuring reliable obstacle detection and collision avoidance in dynamic environments.

Exemplary: Rotary encoder feedback in robot joints, Linear encoder positioning in gantry robots, Potentiometer sensing in gripper fingers, Resolver tracking in heavy-duty robot motors, Capacitive sensing for liquid level detection.

Unit III	**Vision Sensors and Cameras**	**(07 Hours)**

Introduction to Machine Vision Systems: Camera types: RGB, depth, and stereo vision, Overview of machine vision software.

Image Processing Techniques: Basic image processing (edge detection, object recognition), Advanced techniques: 3D vision, SLAM (Simultaneous Localization and Mapping).

Integration of Vision Sensors with Robots: Vision-based robot control, Object tracking, grasping, and visual feedback, Vision sensors in autonomous Mobile Robots (AMRs).

Real World Assignment:

1. Capture objects using RGB (Logitech) and depth cameras (Intel RealSense). Compare accuracy in object dimension measurement.
2. Apply canny edge detection to identify cracks/defects in manufactured parts.

Exemplary: RGB camera-based object recognition for sorting, Depth camera sensing for 3D bin picking, Stereo vision for depth perception in robot navigation, Edge detection for part inspection on assembly lines, 3D vision for precise robotic grasping.

Unit IV	Force and Tactile Sensors	(07 Hours)

Force Sensors: Types of force sensors: strain gauges, piezoelectric, and load cells, Applications in robotic grippers, end-effectors, and tactile feedback, Force sensing for delicate handling and compliance in robots.

Tactile Sensors: Technologies behind tactile sensing: resistive, capacitive, and piezoelectric, Applications of tactile sensors in robots for surface contact and interaction.

Sensor Fusion for Force and Tactile Sensing: Combining multiple sensor inputs for better decision-making, Real-time feedback for adaptive robot behaviour.

Real World Assignment:

1. Design a tactile sensing system using resistive, capacitive, or piezoelectric technologies for a robot end-effector to detect surface contact, texture, and slip during pick-and-place operations.
2. Develop a sensor fusion strategy combining force and tactile sensor inputs for real-time adaptive grip force adjustment in a robotic arm, ensuring stable grasping under varying object weights and surface conditions.

Exemplary: Strain gauge sensing for grip force control in robotic grippers, Piezoelectric sensing for impact detection in end-effectors, Load cell measurement for payload monitoring in robot arms, Force sensing for delicate object handling in food industry.

Unit V	Advanced Sensor Systems and Trends	(07 Hours)

Sensor Networks for Industrial Robotics: IoT (Internet of Things) in robotics, Wireless sensor networks and communication protocols, Distributed sensing systems for large-scale robot fleets.

Wearable and Smart Sensors: The role of wearable sensors in human-robot collaboration, Smart sensors for robots working in unstructured environments.

Emerging Trends in Sensors for Robotics: Artificial intelligence (AI) in sensor data interpretation, Future sensor technologies: LiDAR, 5G for robotic communication, and quantum sensors.

Sensor Calibration and Maintenance: Importance of regular calibration and maintenance procedures, Industry standards and best practices for sensor longevity.

Real World Assignment:

1. Design an IoT-enabled wireless sensor network for monitoring a fleet of mobile robots in a warehouse, selecting appropriate communication protocols for real-time data transmission and centralized control.
2. Develop an AI-based approach for interpreting sensor data from industrial robots to predict equipment failures, recommending appropriate sensor technologies (LiDAR, 5G) for enhanced data collection and analysis.

Exemplary: Wearable sensors for safe human-robot collaboration**,** Smart sensors for robots in unstructured outdoor environments**,** AI-based sensor data interpretation for predictive maintenance**,** LiDAR integration for high-accuracy 3D mapping.

Learning Resources

Text Books:

1. Craig, J. J. (2005). *Introduction to robotics (3rd Ed.).* Pearson Education.
2. Ghoshal, A. (2006). *Robotics: Fundamental concepts & analysis*. Oxford University Press.
3. Luger, G. F. (2008). *Artificial intelligence (5th Ed.).* Pearson.
4. Pratihar, D. K. (2019). *Fundamentals of robotics*. Narosa Publishing House.

Reference Books:

1. Saha, S. K. (2014). *Introduction to robotics*. Tata McGraw-Hill Education.
2. Niku, S. B. (2020). *Introduction to robotics: Analysis, control, applications (3rd Ed.).* John Wiley & Sons.
3. Groover, M., Weiss, M., Nagel, R. N., Odrey, N., & Dutta, A. (2012). *Industrial robotics* (*2nd Ed.)*. McGraw-Hill Education (India).
4. Klafter, R. D., Chmielewski, T. A., & Negin, M. (2009). *Robotic engineering: An integrated approach*. Pearson Education.
5. Russell, S., & Norvig, P. (2003). *Artificial intelligence: A modern approach*. Prentice Hall.
6. Aleksander, I., & Burnett, P. (1987). *Thinking machines*. Oxford University Press.
7. Bench-Capon, T. J. M. (1990). *Knowledge representation: An approach to artificial intelligence*. Academic Press.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Industrial Robotics: Theories
   https://onlinecourses.nptel.ac.in/noc23_me143/preview

2. NPTEL Course: Sensors and Actuators
   https://onlinecourses.nptel.ac.in/noc25_ee76/preview

3. Coursera Course: Basics of Robotics
   https://www.coursera.org/learn/siemens-robotics-course

Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised

PCC-252-RAI: Kinematics of Robot

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**40 Marks**
Practical	**NA**		**End-Semester**	**60 Marks**

Prerequisite:

Engineering Mechanics (ESC-104-CVL),
Basic Electronics Engineering (ESC-101-ETC)

Course Objectives:

The student will be able

1. To introduce students to the fundamentals of robotics including its history, types, components, degrees of freedom, and coordinate systems necessary for understanding robotic kinematics.
2. To enable students to understand and apply geometrical, algebraic, and Denavit-Hartenberg (DH) approaches for deriving and simulating forward kinematics of robotic arms.
3. To equip students with the knowledge of solving inverse kinematics problems using analytical and numerical techniques for both simple and complex manipulators.
4. To develop an understanding of kinematic modeling and simulation of differential drive mobile robots and mobile manipulators in real-world motion scenarios.
5. To foster analytical skills in evaluating manipulator workspace, identifying singularities, and selecting end-effectors for different industrial applications.

Course Outcomes:

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

CO1: DESCRIBE the fundamental concepts of robotics, including classifications, kinematic structures, degrees of freedom, and coordinate systems.

CO2: ANALYZE and **SIMULATE** the forward kinematics of serial manipulators using geometric, algebraic, and Denavit-Hartenberg (DH) methods.

CO3: SOLVE inverse kinematics problems for planar and spatial robots, and apply methods such as analytical approaches and Pieper's solution for 6-DOF arms.

CO4: MODEL and **SIMULATE** differential drive robots and mobile manipulators, considering real-world motion constraints and path planning.

CO5: EVALUATE robotic manipulator configurations for workspace design, singularities, manipulability, and end-effector selection in industrial applications.

Course Contents		
Unit I	**Overview of Robot Kinematics**	**(08 Hours)**

Introduction to Robotics: History, Definitions, Law of robotics, Terminologies, Classifications overview, Links & joints, Degrees of freedom (DOF), Coordinate systems.
Work Volume: Precision, Repeatability & accuracy.
Position and Orientation of Objects: Roll, Pitch and Yaw angles, Joint configuration of five types of serial manipulators, Wrist configuration.
Overview of End Effector: Selection and application of serial manipulators, Singularities, Manipulability of manipulators.

Real World Assignment:

1. Simulate a 2R planar robot (using MATLAB/Python) and plot its workspace.
2. Analyze a 6-DOF robotic arm (e.g., UR5, KUKA) and identify: (a) Joint types (R/P) and their sequence and (b)Wrist configuration (Roll-Pitch-Roll or other).
3. Use a robot simulation tool (e.g., ROS, CoppeliaSim) to demonstrate a singular configuration.

Exemplary:

Analyze industrial robot configurations, optimize work volumes for manufacturing tasks, and select appropriate end-effectors for applications like welding or pick and place operations. The concepts directly apply to programming robotic arms, troubleshooting singularities in production lines, and improving precision in automated systems.

Unit II	**Forward Kinematics - Geometrical and Algebraic Approach**	**(07 Hours)**

Introduction to Forward Kinematics: Need for forward and inverse kinematics equation, Parameters in design and control, Methods of forward and inverse kinematics.
Geometrical and Algebraic Approach in Forward Kinematics Solution: 1-DOF, 2-DOF Planar Robot (2P and 2R), 3-DOF 2RP Spatial Robot.

Real World Assignment:

1. Derive FK equations for a 2R arm and plot end-effector positions for varying θ_1, θ_2 in MATLAB.
2. Compute forward kinematics using transformation matrices for a 2P robot.
3. Study a 6-DOF industrial arm and identify joint types (R/P) and sequence.

Exemplary:

Compute robot end-effector positions for tasks like CNC machining or pick-and-place operations using geometric and algebraic methods. Mastery of forward kinematics is critical for programming robotic arms in manufacturing, animation, and autonomous systems.

Unit III	**Forward Kinematic Modeling – Denavit-Harteberg (DH) Approach**	**(07 Hours)**

Introduction to Forward Kinematic Modeling - Unit circle trigonometry, Translation matrix, Rotation matrix, Euler angles, Quaternion fundamental, Dot and cross products, Frames and joint coordinates, Homogeneous transformation.
D-H Convention and Procedures and Solutions: 3-DOF wrist, RR Planar, 3-DOF RRP, Cartesian, Cylindrical, Spherical, SCARA and Articulated 3-DOF robots, 3-DOF robot with wrist.

Real World Assignment:

1. Apply DH frames to a cylindrical robot (2R + 1P) and Derive DH table and compute forward kinematics using transformation matrices.
2. Apply DH convention to a SCARA (RRP) robot and validate forward kinematics with a commercial SCARA model (e.g., EPSON T3).
3. Model a 3-DOF wrist (RPR) using DH and identify singular configurations via determinant analysis.
4. Compare DH solutions for Articulated vs. SCARA robots.
5. Implement forward kinematics for SCARA configuration and Visualize workspace boundaries.

Exemplary:

Model industrial robots like SCARA or articulated arms using DH parameters, enabling precise control in tasks like assembly or welding. Mastering DH convention is essential for robotics simulation (ROS, Gazebo) and real-world automation programming. Logistics and warehouse automation heavily rely on DH modeling for mobile manipulators that combine robotic arms with autonomous mobile bases, enabling systems like Amazon's warehouse robots to accurately pick and place items of varying sizes and weights.

Unit IV	**Inverse Kinematics**	**(07 Hours)**

Introduction to Inverse Kinematics: Issues in inverse kinematics, Inverse kinematics of 2-DOF planar robot, 2 and 3-DOF planar and spatial robot.
Tool Configuration: Inverse kinematics of 3 axis robot and 6 axis Robot, Inverse kinematics computation, Closed loop solution.

Real World Assignment:

1. Derive inverse kinematics equations for a 2R arm (given end-effector (x, y)) and implement in MATLAB/Python to visualize both solutions.
2. Solve inverse kinematics for a cylindrical robot (2R + 1P) to reach a target (x, y, z).
3. Use Pieper’s method to solve IK for a UR5/KUKA arm and focus on wrist- center point calculation.

Exemplary:

Program industrial robots (e.g., welding arms or CNC machines) by solving inverse kinematics for precise end-effector control. Mastery of inverse kinematics is vital for robotics in manufacturing, animation, and autonomous systems.

Unit V	Kinematic Modeling of Differential Drive Robot	(07 Hours)

Introduction to Kinematic Modelling: Degree of Mobility, Steerability and maneuverability.

Mobile Robot Kinematics: Kinematic model and constraints, Mobile robot workspace, Representation of robot position.

Kinematic Models of Differential Wheel Drive: Fixed wheel and steered wheel, Mobile manipulators and its applications, Swarm robots.

Real World Assignment:

1. Model a differential drive robot (e.g., TurtleBot) in MATLAB/Python and Simulate trajectories for square/circular paths.
2. Simulate 3+ robots forming a pattern (e.g., line, circle) using kinematic models.
3. Integrate a 2-DOF arm on a mobile base (simulated in ROS/Gazebo) and solve inverse kinematics for the arm while the base moves.

Exemplary:

Design autonomous mobile robots (e.g., delivery bots or AGVs) by modeling differential drive kinematics and handling non-holonomic constraints. Skills extend to swarm robotics and mobile manipulators used in logistics and industrial automation.

Learning Resources

Text Books:

1. Schilling, R. J. (2009). *Fundamentals of robotics analysis and control*. PHI Learning.
2. Craig, J. J. (2005). *Introduction to robotics: Mechanics and control (3rd Ed.).* Pearson.
3. Groover, M. P., Weiss, M., Nagel, R. N., & Dutta, A. (2017). *Industrial robotics: Technology, programming, and applications (2nd Ed.).* McGraw-Hill Education.

Reference Books:

1. Janaki Raman, P. A. (1995). *Robotics and image processing: An introduction.* Tata McGraw-Hill.
2. Shames, I. H. (2005). *Engineering mechanics: Statics and dynamics (5th Ed.).* Prentice-Hall of India.
3. Lynch, K. M., & Park, F. C. (2017). *Modern robotics: Mechanics, planning, and control*. Cambridge University Press.
4. Lewis, F. L., Dawson, D. M., & Abdallah, C. T. (2004). *Robot manipulator control: Theory and practice (2nd Ed.).* Marcel Dekker.
5. Spong, M. W., Hutchinson, S., & Vidyasagar, M. (2006). *Robot dynamics and control (2nd Ed.).* Wiley.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Mechanism and Robot Kinematics
   https://nptel.ac.in/courses/112105236
2. NPTEL Course: Robotics
   https://nptel.ac.in/courses/112105249
3. Coursera Course: Robot Kinematics
   https://www.coursera.org/learn/modernrobotics-course2

Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised

PCC-253-RAI: Mechanics of Materials

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**40 Marks**
Practical	**NA**		**End-Semester**	**60 Marks**

Prerequisite:

Engineering Mechanics (ESC-104-CVL)

Course Objectives:

The students will be able

1. To acquire basic knowledge of stress, strain due to various types of loading.
2. To define shear force and bending moment diagram for transverse loading.
3. To determine bending, shear stress, slope and deflection on beam.
4. To solve problems of torsional shear stress for shaft and buckling for the column.
5. To apply the concept of principal stresses and theories of failure.

Course Outcomes:

On completion of the course, learner will be able to:

CO1:**UNDERSTAND** the various types of stresses and strain developed on determinate and indeterminate members.

CO2:**ANALYZE** Shear force and bending moment diagram for various types of transverse loading and support.

CO3:**COMPUTE** the slope & deflection, bending stresses and shear stresses on a beam.

CO4:**CALCULATE** torsional shear stress in shaft and buckling on the column.

CO5:**APPLY** the concept of principal stresses and theories of failure to determine stresses on a 2-D element.

Course Contents

Unit I	Simple Stresses and Strains	(08 Hours)

Simple Stresses & Strains: Introduction to types of loads (Static, Dynamic & Impact Loading) and various types of stresses with applications, Hooke's law, Poisson's ratio, Modulus of Elasticity, Modulus of Rigidity, Bulk Modulus, Interrelation between elastic constants, Stress-strain diagram for ductile and brittle materials, Stresses and strains in determinate and indeterminate beam, Homogeneous and composite bars, Thermal stresses.

Real World Assignment:

1. Compare ductile and brittle materials through stress-strain analysis, strain calculations, and application-based recommendations for robotic gripper design.
2. Calculate shear and bulk moduli, shear stress/strain, and volumetric strain for a soft polymer robotic joint, and interpret Poisson's ratio effect.
3. Analyze thermal stress in a real-world structure by selecting two materials, calculating stress and proposing design modifications to prevent failure.

Exemplary:

A crane lifting a load slowly applies a static load, while a car hitting a barrier experiences an impact load, A copper wire shows ductile failure, while glass breaks brittlely, A steel rail ($\alpha = 12\times10^{-6}/°C$) heated by 50°C develops thermal stress if constrained ($\sigma = \alpha E \Delta T$).

Unit II	Shear Force and Bending Moment Diagrams (SFD and BMD)	(07 Hours)

SFD & BMD: Introduction to SFD, BMD with application, SFD and BMD for statically determinate beam due to concentrated load, uniformly distributed load, uniformly varying load, couple and combined loading, etc., Relationship between rate of loading, shear force and bending moment, Concept of zero shear force, Maximum bending moment, and point of contra-flexure.

Real World Assignment:

1. Analyze SFD and BMD for a 6-axis robotic manipulator arm under point loads, UDL, and couples to identify maximum bending moment and critical points.
2. Perform SFD and BMD calculations for a SCARA robot horizontal arm under UDL, point loads, and applied moment in high-speed packaging operations.
3. Analyze SFD and BMD for a surgical robotic arm with slender instruments, trocar support, or micro-surgical tools for laparoscopic precision applications.

Exemplary:

A cantilever beam model applies to robotic arms, A robot leg modeled as a simply supported beam with uniformly varying load, In a SCARA robot arm, the elbow joint experiences high bending moment.

Unit III	Bending and Shear Stresses	(07 Hours)

Bending and Shear Stress on a Beam: Introduction to bending and shear stresses on a beam with application, Theory of Simple bending, assumptions in pure bending, derivation of flexural formula, Moment of inertia of common cross section (Circular, Hollow circular, Rectangular, I & T), Bending stress distribution along the same cross-section, Shear stress distribution diagram along the standard cross-section.

Slope & Deflection on a Beam: Introduction to slope & deflection on a beam with application, slope, deflection and radius of curvature.

Real World Assignment:

1. Analyze robotic arm bending stress analysis with varying cross section I or rectangular.
2. Analyze drone frame shear stress analysis for hollow sections.
3. Analyze shear stress for a robotic gripper finger under grasping force by comparing cross-sections.

Exemplary:
Bending stress in robotic arms, Shear stress helps prevent joint and link deformations in high-speed robotic manipulators, Optimizing the moment of inertia in robotic limb cross-sections improves dynamic stability and reduces vibrations.

Unit IV	Torsion and Buckling	(07 Hours)

Torsion of Circular Shafts: Introduction to torsion on a shaft with application, Basic torsion formulae and assumption in torsion theory, Torsion in stepped and composite shafts, Torque transmission on strength and rigidity basis, Torsional Resilience, Torsion on thin-walled tubes.

Buckling of Columns: Introduction to buckling of column with its application, Different column conditions and critical, Safe load determination by Euler's theory, Limitations of Euler's Theory.

Real World Assignment:

1. Design of robotic wrist joint shaft and compare it for weight saving.
2. Determination the torsional resilience of industrial conveyor stepped shaft.
3. 3D printer vertical support column (buckling under self-weight).
4. Create a short educational video explaining torsion or bucking analysis for a real drone/robotic component with measurements, calculations, design improvements, and sensitivity analysis.

Exemplary:
Torsion formula helps design robotic joint shafts, Calculating torsional resilience ensures robotic joints absorb and release energy without permanent deformation during sudden stops, Lightweight robotic limbs use thin-walled tubes to maximize torsional strength while minimizing inertia.

Unit V	Principal Stresses and Theories of Failure	(07 Hours)

Principal Stresses: Introduction to principal stresses with application, Transformation of plane stress, Principal stresses and planes (Analytical method and Mohr's Circle), Stresses due to combined normal and shear stresses.

Theories of Elastic Failure: Introduction to theories of failure with application, Maximum principal stress theory, Maximum shear stress theory, Maximum distortion energy theory, Maximum principal strain theory, Maximum strain energy theory.

Real World Assignment:

1. Calculation of (Principal Stresses) for aircraft wing skin stress analysis.
2. Compute principal stresses, check for failure theories - robot arm joint bearing.
3. Prepare poster analyzing failure of a robotic component using Principal Stress, Von Mises, or Tresca theories with safety factor calculations and design solutions.

Exemplary:

Calculating principal stresses ensures robotic grippers and joints can handle multi-axis loading without structural failure, Mohr's Circle visually confirms critical stress orientations in robotic linkages, preventing material yield in dynamic environments, analyzing combined normal and shear stresses in robotic actuators guarantees durability under simultaneous bending and torsional loads.

Learning Resources

Text Books:

1. Bansal, R. K. (2010). *Strength of materials*. Laxmi Publications.
2. Ramamurtham, S. (2003). *Strength of materials*. Dhanpat Rai Publishing.
3. Rattan, S. S. (2008). *Strength of materials*. Tata McGraw-Hill.
4. Sarkar, B. K. (2007). *Strength of materials*. McGraw-Hill Education.
5. Singer, F. L., & Pytel, A. (1980). *Strength of materials (2nd Ed.)*. Harper & Row.
6. Hibbeler, R. C. (2017). *Mechanics of materials (10th Ed.)*. Pearson.

Reference Books:

1. Popov, E. P. (1968). *Introduction to mechanics of solids*. Prentice Hall.
2. Ryder, G. H. (1969). *Strength of materials*. Macmillan.
3. Beer, F. P., & Johnston, E. R. (1981). *Strength of materials*. CBS Publishers.
4. Gere, J. M. (2001). *Mechanics of materials (5th Ed.)*. CL Engineering.
5. Timoshenko, S., & Young, D. H. (1968). *Strength of materials (3rd Ed.)*. CBS Publishers.

MOOC / NPTEL/YouTube Links:

1. Swayam Course: Strength of Materials
   https://onlinecourses.nptel.ac.in/e-learning/preview/noc23_me140

2. NPTEL Course: Mechanics of Materials
   https://onlinecourses.nptel.ac.in/e-learning/preview/noc22_ce54

3. Coursera Course : Mechanics of Materials I: Fundamentals of Stress & Strain and Axial Loading
   https://www.coursera.org/learn/mechanics-1

Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised

PCC-254-RAI: Sensors for Industrial Robotics Lab

Teaching Scheme		Credits	Examination Scheme	
Theory	**NA**	**2**	**Oral**	**NA**
Practical	**2 Hours/Week**		**Practical**	**50 Marks**

Prerequisite:
Basic Electronics Engineering (ESC-101-ETC),
Basic Electrical Engineering (ESC-102-ELE)

Course Objectives:

The student will be able

1. To recall and describe the principles of operation of proximity sensors.
2. To understand how machine vision works, including the principles of image processing.
3. To understand the technologies behind temperature and pressure sensing.
4. To apply their knowledge of motion and position sensors (encoders, accelerometers, gyroscopes) to robotics.
5. To implement sensor fusion techniques, combining data in application of robotics engineering.

Course Outcomes:

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

CO1: ANALYZE the working principles, calibration methods, and applications of proximity, force, temperature, pressure, and flow sensors used in industrial robotics.

CO2: IMPLEMENT machine vision systems for object detection and recognition, and integrate motion sensors for position and motion tracking.

CO3: CLASSIFY and interface sensors with robotic systems and interpret their output.

CO4: APPLY sensor fusion techniques to combine multi-sensor data for enhanced accuracy, reliability, and decision-making in robotic systems.

CO5: DESIGN and **DEVELOP** a mini-project that addresses a real-world industrial problem or creative application using appropriate sensor integration and validation.

Laboratory Experiments/Assignments	
The student must complete the following activity for their Term Work Journal (Any 8 Experiments)	
Practical 1	**Proximity Sensors** Understand principles of operation of capacitive, inductive, and optical proximity sensors and learn calibration and testing of proximity sensors.
Practical 2	**Vision Systems** Understand machine vision and image processing for object detection and recognition.
Practical 3	**Force Sensors** Understand force and torque sensing principles using force sensors: Strain gauge, Load Cell and learn the force sensing in industrial robotics.
Practical 4	**Temperature and Pressure Sensors** Understand temperature and pressure sensing technologies using temperature and pressure sensors in robotic systems.
Practical 5	**Flow Sensors** Understand flow principles using flow sensors in robotics.
Practical 6	**Sensor Fusion and Integration** Understand Principles of motion and position sensing, encoders, accelerometers, and gyroscopes and implement applications of motion and position sensors in robotics.
Practical 7	**Advanced Topics and Emerging Trends** Presentation on a recent advancement in any one specific type of sensor technologies for industrial robotics based on following points: a) Integration of AI and machine learning with sensor data, b) Ethical considerations and challenges in sensor-enabled robotics, etc.
Practical 8	**Mini Project Work** Students work on a mini project that utilizes their understanding of sensors in industrial robotics to address a real-world issue or create a creative application.
Practical 9	**Industry Visit** Industrial visit to Automation Industry/Case Studies.

Learning Resources

Text Books:

1. Pawlak, A. M. (2018). *Sensors and actuators in mechatronics: Design and applications*. CRC Press.
2. Correll, N., Hayes, B., & Memarzadeh, A. (2019). *Introduction to autonomous robots: Mechanics, sensors, actuators, and algorithms*. Chapman and Hall/CRC.
3. De Silva, C. J. S. (2017). *Industrial sensors and instrumentation*. CRC Press.
4. Regtien, P. P. L. (2012). *Sensors for mechatronics*. Elsevier.
5. Ida, N. (2013). *Sensors, actuators, and their interfaces: A multidisciplinary introduction (2nd Ed.)*. Scitech Publishing Inc.

Reference Books:

1. Niku, S. B. (2020). *Introduction to robotics: Analysis, control, applications (3rd Ed.).* John Wiley & Sons Ltd.
2. Groover, M., Weiss, M., Nagel, R. N., Odrey, N., & Dutta, A. (2012). *Industrial robotics (2nd Ed.).* McGraw Hill Education (India) Pvt. Ltd.
3. Russell, S., & Norvig, P. (2003). *Artificial intelligence: A modern approach*. Prentice Hall.
4. Aleksander, I., & Burnett, P. (1987). *Thinking machines*. Oxford University Press.
5. Bench-Capon, T. J. M. (1990). *Knowledge representation: An approach to artificial intelligence*. Academic Press.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Industrial Robotics: Theories for Implementation
   https://onlinecourses.nptel.ac.in/noc23_me143/preview

2. NPTEL Course: Sensors and Actuators
   https://onlinecourses.nptel.ac.in/noc25_ee76/preview

3. Coursera Course: Basics of Robotics
   https://www.coursera.org/learn/siemens-robotics-course

Real World Assignment:

1. Use inductive sensors to detect metal objects on a conveyor belt and capacitive sensors for non-metallic items.
2. Integrate a strain-gauge sensor to adjust grip force for fragile objects.
3. Deploy temperature (LM35) and pressure (MPX5050) sensors on a mobile robot to monitor factory conditions.
4. Implement IMU (MPU6050) and encoders to stabilize a two-wheeled robot.
5. Integrate LiDAR, IMU, encoder data (ROS) for SLAM in a mock warehouse.

Exemplary: Proximity sensors detect objects, Vision systems enable quality control, Force sensors ensure delicate handling, and temperature/pressure monitors maintain safety. Motion tracking and sensor fusion allow precise navigation, while AI integration enables predictive maintenance. Mini-projects combine these technologies for real-world applications like automated inspection and smart agriculture, using tools like Arduino, ROS, and OpenCV to prepare students for Industry 4.0 careers.

<table>
<tr><th colspan="5">Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern)</th></tr>
<tr><th colspan="5">PCC-255-RAI: Material Testing and Characterization Lab</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th>Credits</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>Theory</td><td>NA</td><td rowspan="2">1</td><td>Oral</td><td>NA</td></tr>
<tr><td>Practical</td><td>2 Hours/Week</td><td>Practical</td><td>50 Marks</td></tr>
</table>

Prerequisite:

Materials and Manufacturing (PCC-202-RAI)

Course Objectives:

The student will be able

1. To develop hands-on competence in conducting standardized mechanical tests (tensile, compression, torsion, impact, flexural) using ASTM protocols and interpreting material properties.
2. To cultivate analytical skills for comparing experimental data with theoretical models, identifying discrepancies, and validating material behavior under different loading conditions.
3. To investigate failure mechanisms through non-destructive testing (NDT) and advanced microscopy (SEM), correlating microstructural features with macroscopic material performance.
4. To professionalize technical communication by documenting test procedures, results, and industrial observations in structured reports adhering to engineering standards.
5. To synthesize multidisciplinary approaches by integrating experimental testing, computational simulations (FEA), and microscopic analysis for holistic material characterization.

Course Outcomes:

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

CO1: PERFORM mechanical tests such as tensile, compressive, torsion, impact, and flexural tests using standardized equipment and calculate material properties as per the ASTM standards.

CO2: ANALYZE experimental data from different testing such as tensile, compressive, torsion, impact, and flexural tests and validate results against theoretical models.

CO3: EXAMINE the failure mechanism and behaviour using non-destructive testing and electron microscopy.

CO4: ORGANIZE technical findings in professional formats, including lab reports with standardized data presentation and field visit reports with industrial observations.

CO5: DEVELOP integrated test protocols combining experimental methods with simulation (FEA) and microscopy (SEM) for comprehensive material characterization.

Laboratory Experiments/Assignments	
The student shall complete the following activity as a Term Work Journal.	
Practical 1	**Tension Test** 1. Determination of modulus of elasticity of metallic specimens using Universal Testing Machine (UTM). 2. Determination of the Poisson's ratio of a metallic specimen in the linear elastic range of loading. 3. Validation of experimental results of tension tests using ductile and brittle materials.
Practical 2	**Compression Test** 1. Determination of modulus of elasticity of metallic specimens using Universal Testing Machine (UTM). 2. Determination of the Poisson's ratio of a metallic specimen in the linear elastic range of loading. 3. Validation of experimental results of Compression tests using ductile and brittle materials.
Practical 3	**Impact Test** 1. Conduction of Impact test for steel, aluminium, and composite materials as per ASTM standards. 2. Estimation of Notch Toughness of the metallic bar using Charpy/Izod Impact Testing Machines. 3. Compare and conclude on failure behavior using experimental results.
Practical 4	**Hardness Test** 1. Conduction of Hardness Test using Brinell and Rockwell test rigs as per ASTM standards. 2. Measurement of Hardness on test samples should be before and after case harden and core harden heat treatment. 3. Compare and conclude hardness behavior for different heat-treated materials.
Practical 5	**Torsion Test** 1. Conduction of Torsion Test on solid and hollow metallic test specimens per ASTM standards. 2. Measurement of modulus of rigidity and modulus of rupture. 3. Compare torsional properties for different sections and materials.

Practical 6	**Flexural Test** 1. Conduction of three point/four point Bending or Flexural Test on metallic specimens per ASTM standards. 2. Measurement of flexural modulus and flexural strength.
Practical 7	**Non-destructive Tests** 1. Study and analysis of given sample using any one of the Non-destructive tests: Dye Penetrant Test/ Magnetic Particle test/ Ultrasonic Test. 2. Samples can be collected from various failures occurring with automobiles, machine parts, household appliances, etc.
Practical 8	**Demonstration on Microscopy Observation** 1. Field visits to Govt. Lab/COEP for demonstration on Scanning Electronic Microscopy (SEM). 2. Observations of SEM images and understanding of failure behaviour. 3. Preparation of field visit report.
Practical 9	**Demonstration of Component Test Rig Testing** 1. Visit to Govt. Lab such as CIRT, ARAI, NCL, etc. for demonstration on Test Rig. 2. Testing of components such as leaf spring, wheel, ball joint, steering, etc. 3. Compare component and specimen test results and validate.
Practical 10	**Demonstration on Simulation of Testing** 1. Preparation of specimens and test conditions in any simulation software, such as ANSYS, Hypermesh, FreeFEM, FetchCAD, etc. 2. Conduct a simulation for any type of testing such as tensile, compressive, impact, fatigue, and compare the results with experimental data for validation. 3. Conduct a simulation study in group of 4-5 students.
Practical 11	**Virtual Labs** Perform any one test on Virtual Lab (VLab) from the list (VLab- IIT Mumbai): a) Tensile Test on Mild steel b) Tensile Test on Cast Iron c) Compression Test on Mild Steel d) Compression Test on Cast Iron e) Direct shear test on Mild steel Rod f) Direct Shear test on Timber Specimen g) Direct shear test on Mild steel Plate h) Bending Test on Mild steel i) Torsion Test on Mild Steel

Learning Resources

Text Books:

1. Verma, D. S., Khan, L. U., Kumar, S., & Khan, S. B. (2018). *Handbook of materials characterization*. Springer International Publishing.
2. Bhargava, A. K., & Sharma, C. P. (2014). *Mechanical behaviour & testing of materials*. PHI Learning.
3. Avner, S. H. (2017). *Physical metallurgy (2nd Ed.).* McGraw Hill Education.
4. Raghavan, V. (2015). *Material science and engineering (5th Ed.)*. Prentice Hall of India.
5. Ashby, M. F. (2016). *Materials selection in mechanical design (5th Ed.)*. Butterworth-Heinemann.

Reference Books:

1. Gdoutos, E., & Konsta-Gdoutos, M. (2024). *Mechanical testing of materials.* Springer Cham.
2. Prasad, J., & Krishnadas Nair, C. G. (2011). *Non-destructive test and evaluation of materials (2nd Ed.)*. McGraw-Hill Education.
3. Ranganathan, N. (2016). *Materials characterization: Modern methods and applications*. CRC Press.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Mechanical Behavior of Materials
   https://nptel.ac.in/courses/113106101
2. NPTEL Course: Theory and Practice of Non-Destructive Testing
   https://nptel.ac.in/courses/113106070
3. NPTEL Course: Scanning Electron/Ion/Probe Microscopy in Materials Characterization
   https://nptel.ac.in/courses/113105100

Real World Assignment:

1. Study on conduction of tensile testing on turbine blades, bumpers, racquet strings, etc.
2. Calculation of bending stress on aircraft wing and cantilever cranes using simulation software.
3. Inspection of failure samples and evaluate the location of sub / deep surface flaws using Dye Penetrant/ Magnetic Particle Testing.
4. Visit to heat treatment plant/lab for hardening process.
5. Conduct Charpy/Izod impact tests on plastic and metal specimens at different temperatures. Analyze fracture behavior and ductile-to-brittle transition.
6. Test fiber-reinforced composites under three-point bending. Calculate flexural strength and modulus; compare with theoretical predictions.

7. Study on conduction of tensile testing on turbine blades, bumpers, racquet strings, etc.
8. Calculation of bending stress on aircraft wing and cantilever cranes using simulation software.
9. Inspection of failure samples and evaluate the location of sub / deep surface flaws using Dye Penetrant/ Magnetic Particle Testing.
10. Visit to heat treatment plant/lab for hardening process.
11. Conduct Charpy/Izod impact tests on plastic and metal specimens at different temperatures. Analyze fracture behavior and ductile-to-brittle transition.
12. Test fiber-reinforced composites under three-point bending. Calculate flexural strength and modulus; compare with theoretical predictions.
13. Perform cyclic loading tests on metallic or composite samples to determine fatigue life. Plot S-N (Stress vs. Cycles) curves and analyze failure modes.
14. Prepare metallographic samples (grinding, polishing, etching). Examine grain structures of steel, cast iron, and aluminum under a microscope. Relate microstructure to mechanical properties.
15. Perform XRD analysis to identify crystal structures and phases in alloys.

Exemplary:

Fatigue testing of robotic arm joints for long-term reliability, Tensile/compression tests on carbon fiber to optimize robot weight, Charpy tests on exoskeleton components for shock absorption, Bend testing of flexible PCB substrates for robotic sensors.

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
MDM-271-RAI: Biomechanics and Biomaterials				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**2 Hours/Week**	**2**	**CCE**	**50 Marks**
Practical	**NA**		**End-Semester**	**NA**

Prerequisite:

Engineering Mechanics (ESC-104-CVL),
Materials and Manufacturing (PCC-202-RAI)

Course Objectives:

The student will be able

1. To introduce fundamental concepts of biomechanics.
2. To explore applied biomechanics in orthopaedics.
3. To familiarize students with different classes of biomaterials (metals, polymers, ceramics) and their properties.
4. To study various biomaterials and their use in implants, stents, and prosthetics.
5. To understand mechanical testing methods, degradation of biomaterials, and regulatory standards for biomedical applications.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: **EXPLAIN** the mechanical behaviour of biological tissues (bone, cartilage, tendons) and analyse human movement using kinematic and kinetic principles.

CO2: **EVALUATE** orthopaedic biomechanics concepts, including fracture fixation, joint replacement designs, and cardiovascular biomechanics.

CO3: **CLASSIFY** biomaterials (metals, polymers, ceramics) based on their bulk/surface properties and justify their selection for medical applications.

CO4: COMPARE different biomaterials (stainless steel, titanium, hydroxyapatite) and their applications in orthopaedics, dentistry, and cardiovascular implants.

CO5: PERFORM mechanical testing of biomaterials, assess degradation in biological environments, and apply International (ISO) and Indian (BIS) standards in biomedical device development.

Course Contents		
Unit I	**Fundamentals of Biomechanics**	**(06 Hours)**

Introduction to Biomechanics: Definition and scope, Historical development, Interdisciplinary nature (engineering, biology, medicine).

Mechanical Properties of Biological Tissues: Bone - Cortical vs trabecular bone, Anisotropic behavior, Stress-strain relationships, Cartilage-Viscoelastic properties, Load distribution mechanisms, Tendons and ligaments- Nonlinear elasticity, Stress relaxation and creep.

Biomechanics of Human Movement: Kinematic analysis- Gait cycle phases, Joint angle measurements, Kinetic analysis- Ground reaction forces, Inverse dynamics.

Real World Assignment:

1. Students first measure their vertical jump height using the chalk mark method, then apply kinematic equations to calculate takeoff velocity and peak ground reaction forces.
2. Using Open Sim's gait2392 musculoskeletal model, students input motion capture data to analyze joint moments and muscle forces during walking.
3. Using free motion analysis software (Kinovea or Dartfish), students compare walking patterns between young and elderly subjects.

Exemplary:

1. Biomechanics applies engineering principles to biological systems, Evolving through interdisciplinary collaboration to analyze movement and tissue mechanics in medicine and sports.
2. Gait analysis (kinematics) and force measurements (kinetics) improve prosthetics, Athletic performance and diagnose musculoskeletal disorders.

Unit II	**Orthopedic, Cardiovascular and Clinical Biomechanics**	**(06 Hours)**

Orthopaedic Biomechanics: Fracture mechanics - Healing stages, Fixation methods (Plates, Screws, Nails), Joint Replacements - Hip prosthesis design, Wear analysis of bearing surfaces.

Cardiovascular Biomechanics: Heart valve mechanics- Leaflet stresses, Prosthetic valve designs.

Clinical Applications: Gait analysis in rehabilitation, Prosthetic limb design, Orthotic device development.

Real World Assignment:

1. Investigate wear mechanisms in hip implant bearing surfaces (metal-on-polyethylene vs. ceramic-on-ceramic) using literature or computational modeling.
2. Sketch and prototype a simple orthotic device using 3D printing or low-cost materials, considering load distribution and patient comfort.

Exemplary:
Test 3D-printed fracture plates, Simulate heart valve stresses with FEA/CFD, and Optimize prosthetics using gait analysis to solve real clinical biomechanics challenges.

Unit III	**Introduction and Properties of Biomaterials**	**(06 Hours)**

Introduction: Introduction to biomaterials, Classes of materials - Metals, Polymers, Bioresorbable and Biodegradable materials.

Properties of Materials: Bulk and Surface properties and their characterization, Mechanical properties of biomaterials.

Real World Assignment:

1. Perform tensile/compression tests in lab or via simulation software like ANSYS on different biomaterials (e.g., stainless steel, hydrogel).
2. Use microscopy or contact angle measurements to analyze surface roughness/wettability of biomaterials.
3. Investigate a real-world failure (e.g., metal corrosion in implants, polymer wear in joints). Suggest improvements.

Exemplary:

Test 3D-printed metal/polymer implants for strength, Simulate biodegradable suture degradation, and Analyze hip implant wear to link biomaterial properties to real medical applications.

Unit IV	Types and Testing of Materials	(06 Hours)

Types of Materials: Stainless steel, Titanium, Alloys, Polymers, Bio-ceramics, Biodegradable metals, Ceramics and composites, Alumina, Zirconia, Hydroxyapatite, Applications of materials in orthopedic, Dental, Prostheses, Cardiac stent, etc.

Testing of Materials: Mechanical testing of materials, World and Indian standards, Specifications degradation of materials in the biological environment, Effects of the biological environment on metals, Polymers and ceramics.

Real World Assignment:

1. Perform hardness/tensile tests on stainless steel (316L) vs. Titanium (Ti-6Al-4V) for bone plates.
2. Investigate real cases of Ceramic (ZrO_2) hip liner fractures.
3. Choose a medical device (e.g., dental implant, cardiac stent, hip replacement) and justify the material used (e.g., titanium alloy, hydroxyapatite, biocomposite, etc.) based on mechanical properties, biodegradability, and clinical requirements.

Exemplary:

Test titanium vs. stainless steel for implants, Study biodegradable screw corrosion, Apply hydroxyapatite coatings, and Analyze zirconia hip failures to apply material science in real medical devices.

Learning Resources

Text Books:

1. Nordin, M., & Frankel, V. H. (2012). *Basic biomechanics of the musculoskeletal system (4th Ed.).* Lippincott Williams & Wilkins.
2. Ratner, B. D., Hoffman, A. S., Schoen, F. J., & Lemons, J. E. (2013). *Biomaterials science: An introduction to materials in medicine (3rd Ed.).* Academic Press.
3. Ozkaya, N., Leger, D., Goldsheyder, D., & Nordin, M. (2017). *Fundamentals of biomechanics: Equilibrium, motion, and deformation (4th Ed.).* Springer.
4. Hall, S. J. (2019). *Basic biomechanics (8th Ed.).* McGraw-Hill Education.

Reference Books:

1. Mow, V. C., & Huiskes, R. (2005). *Basic orthopaedic biomechanics and mechano-biology (3rd Ed.).* Lippincott Williams & Wilkins.
2. Black, J., & Hastings, G. (2013). *Handbook of biomaterial properties (2nd Ed.).* Springer Science & Business Media.
3. Fung, Y. C. (2017). *Biomechanics: Mechanical properties of living tissues (2nd Ed.).* Springer.
4. Temenoff, J. S., & Mikos, A. G. (2008). *Biomaterials: The intersection of biology and materials science*. Pearson Prentice Hall.
5. Bronzino, J. D. (2006). *The biomedical engineering handbook: Tissue engineering and artificial organs (3rd Ed.).* CRC Press.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Biomechanics
   https://onlinecourses.nptel.ac.in/noc23_bt04/preview

2. NPTEL Course: Introduction to Biomaterials
   https://nptel.ac.in/courses/113104009

3. NPTEL Course: Biomedical Signal Processing
   https://nptel.ac.in/courses/108105101

4. Coursera Course: Industrial Biotechnology
   https://www.coursera.org/learn/industrial-biotech

<table>
<tr><th colspan="5">Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised</th></tr>
<tr><th colspan="5">VSE-281-RAI: CNC and System Simulation Lab</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th>Credits</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>Theory</td><td>NA</td><td rowspan="2">1</td><td>Oral</td><td>NA</td></tr>
<tr><td>Practical</td><td>2 Hours/Week</td><td>Practical</td><td>50 Marks</td></tr>
</table>

Prerequisite:

Programming & Problem Solving (PCC-151-ITT),
Materials and Manufacturing (PCC-202-RAI),
Computer Aided Design Lab (VSE-231-RAI)

Course Objectives:

The student will be able

1. To enable students to create, simulate, and optimize manual part programs using standard G and M codes for both turning and milling operations.
2. To train students in using CAM software for 3D part modeling, toolpath generation, and simulation, ensuring seamless transition from CAD designs to executable CNC programs.
3. To enable hands-on experience in setting up CNC machines, verifying programs through simulation, and executing turning operations to produce components within specified tolerances.
4. To familiarize students with Flexible Manufacturing Systems (FMS) components (AGVs, AS/RS, PLCs) and their integration, enabling configuration of simple automated workflows.
5. To empower students to design and implement Python-based tools that automate CNC operations, generate G-code, and optimize manufacturing processes for improved efficiency.

Course Outcomes:

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

CO1: DEVELOP and **SIMULATE** manual part programs using standard G and M codes for turning and milling operations.

CO2: USE CAM software to model mechanical components and generate CNC programs for turning and milling operations.

CO3: EXECUTE CNC turning operations by preparing, simulating, and running verified part programs on CNC machines.

CO4: ANALYZE Flexible Manufacturing Systems (FMS) architecture, including AGVs, AS/RS, and PLCs, and configure basic automated workflows.

CO5: DESIGN and **IMPLEMENT** Python-based tools for CNC automation, G-code generation, and manufacturing process optimization.

Laboratory Experiments/Assignments	
The student shall complete the following activity as a Term Work Journal.	
Practical 1	**Introduction to CNC Machine and Tools** 1. A study on the working principle, construction, and tooling requirement CNC Machine tool. 2. Demonstration on working of CNC machine and tools.
Practical 2	**Manual Part Programming: M & G Codes** 1. Generate G and M Code for manual part programming 2. M & G coding for turning, step turning, and milling part geometry as per ISO (DIN 66025) and RS274 standards.
Practical 3	**Introduction to CAM Software** 1. Introduction to Graphic User Interface (GUI) and toolbars. 2. Generation of CAD neutral file and importing. 3. Introduction to CAM turning and CAM milling.
Practical 4	**CAM Turning: Part Modeling and Simulation** 1. Modelling of Mechanical Component using any 3D CAD software. 2. Preparing CNC turning part program using any CAM software.
Practical 5	**CAM Milling: Part Modeling and Simulation** 1. Modelling of Mechanical Component using any 3D CAD software. 2. Preparing CNC milling part program using any CAM software.
Practical 6	**Execution on CNC Machine: CNC Turning** 1. Preparation of CAM part program and verification on CNC machines. 2. Machining of a given component using CNC machine tool.
Practical 7	**Visits to Flexible Manufacturing Systems (FMS) Facility** 1. Study FMS architecture (CNC machines, AGVs, AS/RS, DNC systems). 2. Map hardware (robotic arms, conveyors, PLCs) and software (MES, SCADA). 3. Configure a simple path for automated guided vehicles.
Practical 8	**System Simulation using Program Interface** Students should form groups of 3-4 members to collaboratively complete the following assignments: 1. Write a Python script to generate G-code for simple linear and circular motion using user input (X, Y, Z, F, etc.). 2. Use Python (e.g., matplotlib) to visualize tool paths from G-code files. 3. Develop a Python script that removes redundant or repeated G-code commands from a file. 4. Write a program that checks G-code syntax and highlights unsupported or unsafe commands. 5. Automate the generation of G-code for basic step turning operations with user inputs for diameters and lengths. 6. Build a Python program to generate milling G-codes for square or circular pocket paths.

	7. Write a Python script to automatically import STEP/IGES files into Mastercam. 8. Display real-time tool position updates by reading simulated CNC feedback files or serial stream. 9. Optimize spindle speed (RPM) and feed rate (mm/rev) to maximize material removal rate (MRR) while respecting tool life constraints. 10. Prepare program for various applications *CAD Model → Python Optimization → G-Code Generation → CNC Execution* 11. Implement statistical process control (SPC) charts to detect manufacturing defects using Python. 12. Use real-time cutting force data (simulated) to dynamically adjust feed rates using PID control logic in Python. 13. Recommend tools based on feature dimensions (e.g., pocket radius ≤ endmill diameter). 14. Develop an algorithm to find the shortest path for Automated Guided Vehicles in a warehouse layout. 15. Develop an algorithm to group similar product orders into batches, minimizing changeover time between productions.

Learning Resources

Text Books:

1. Pabla, B. S., & Adithan, M. (2012). *CNC machines (3rd Ed.)*. New Age International (P) Ltd.
2. Smid, P. (2008). *CNC programming handbook (3rd Ed.)*. Industrial Press.
3. Fitzpatrick, M. (2019). *Machining and CNC technology (4th Ed.)*. McGraw-Hill Education.
4. Monk, S. (2016). *Programming Arduino: Getting started with sketches (2nd Ed.)*. McGraw-Hill Education.
5. Radhakrishnan, P. (2018). *Computer numerical control machines and computer aided manufacture*. New Age International.
6. Groover, M. P. (2007). *Automation, production systems, and computer-integrated manufacturing (2nd Ed.)*. Pearson Education India.

Reference Books:

1. Kief, H. B., Roschiwal, H. A., & Schwarz, K. (2021). *The CNC handbook: Digital manufacturing and automation from CNC to Industry 4.0*. Industrial Press.
2. Smid, P. (2008). *CNC programming handbook (3rd Ed.)*. Industrial Press.
3. Stewart, J. M. (2017). *Python for engineers and scientists*. Cambridge University Press.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Computer Numerical Control CNC of Machine Tools and Processes
   https://nptel.ac.in/courses/112105211
2. NPTEL Course: Elements of metal cutting, Machine tools, gear cutting and CNC machining
   https://nptel.ac.in/courses/112105306
3. Coursera Course: Elements of Computer Aided Manufacturing
   https://www.coursera.org/learn/elements-of-computer-aided-manufacturing

Real World Assignment:

1. Bottleneck Analysis in Assembly Lines.
2. Predict tool wear in real-time using sensor data and machine learning.
3. Verify G-code programs for errors before execution.
4. Calculate the optimal order quantity to minimize inventory costs using the Economic Order Quantity formula.
5. Schedule jobs using the Shortest Processing Time (SPT) rule to reduce average waiting time.
6. Build a CNN model (OpenCV + PyTorch) to automatically categorize product defects from camera images on the assembly line.
7. Bottleneck Analysis in Assembly Lines.
8. Predict tool wear in real-time using sensor data and machine learning.
9. Verify G-code programs for errors before execution.
10. Calculate the optimal order quantity to minimize inventory costs using the Economic Order Quantity formula.
11. Schedule jobs using the Shortest Processing Time (SPT) rule to reduce average waiting time.
12. Build a CNN model (OpenCV + PyTorch) to automatically categorize product defects from camera images on the assembly line.
13. Create a simulation (SimPy) to reassign workers between stations based on real-time production bottlenecks.
14. Develop a cutting pattern optimizer (genetic algorithm) to minimize scrap when slicing sheets/rolls into smaller parts.
15. Apply machine learning (scikit-learn) to predict cutting tool failure from sensor data, reducing unplanned downtime.

Exemplary:

Modern manufacturing industry, particularly in sectors such as automotive and aerospace, Companies like Fanuc and ABB are exemplary in the robotic industry, demonstrating advanced integration of CNC machines with robotic automation.

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
AEC-282-RAI: Technical Communication and Soft Skills				
Teaching Scheme		**Credit**	**Examination Scheme**	
Practical	**2 Hours/Week**	**2**	**Term Work**	**50 Marks**
Tutorial	**1 Hours/Week**		**Practical**	**NA**

Prerequisites:

Professional Communication Skills (AEC-101)

Course Objectives:

The student will be able

1. To inculcate professional and ethical attitude at the workplace.
2. To enhance communication and interpersonal skills.
3. To develop effective employability skills.
4. To improve written skills for technical documentation.
5. To develop technical presentation skills.

Course Outcomes:

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

CO1: APPLY group discussion techniques in professional situations.

CO2: USE employability skills to optimize career opportunities.

CO3: EMPLOY storytelling techniques for effective presentation.

CO4: PREPARE technical documents using appropriate style, format, and language.

CO5: DEMONSTRATE interpersonal skills in professional and personal situations.

Course Contents		
Unit I	**Written Communication Skills**	**(06 Hours)**
Resume Writing: Types of Resumes, Structure, Content, and Formatting of Resume. **Email Writing:** Purpose and importance of Email in Professional Contexts, Types of Emails, Email structure overview, The fundamentals of email structure, Purpose - Driven Email writing.		
Real World Assignment: Write professional email on: 1. Requesting an informational interview. 2. Following up on a job application. 3. Addressing a complaint to a service provide.		
Exemplary: Job applications, Professional networking, Online profiles (LinkedIn).		
Unit II	**Corporate Story Telling**	**(06 Hours)**
Interview Skills: Types and modes of interview, Preparation for interview, Dos and Don’ts of interview, frequently asked questions during interview. **Pitch & Presentation Skills:** Elevator pitch, Product stories, Event stories, Stories in presentations, Storytelling in SOP’s and interviews, Storytelling to manage conflict or to motivate.		
Real World Assignment: 1. Prepare & present a PPT on any technical topic. 2. Perform a mock pitch to investors. 3. Role plays for conducting a corporate interview for recruitment.		
Exemplary: Project presentation, Group pitching competition, Research work/proposal.		
Unit III	**Technical Writing and Documentation**	**(06 Hours)**
Research Article Writing: Finding and refining a research topic, Structuring the research article, Structure and components of a technical report, Academic language and style, Referencing and Citations. **Meeting Documentation:** Planning layout of meetings, Observing meeting decorum, Drafting Notice, Agenda, and Minutes of Meeting.		
Real World Assignment: 1. Prepare a technical report on Mini project /PBL/case study. 2. Simulate a team project meeting (e.g., for a college event or class activity). Assign roles and have students write a formal agenda before and minutes of meeting after, including action items and responsibilities. 3. Case study on any research article writing.		
Exemplary: Research paper writing, Research proposal writing, Minutes of meeting.		

Unit IV	Professional Ethics	(06 Hours)

Professional Ethics: Effective work habits, Accountability, Integrity, and Excellence.
Time Management: Importance of time management, Cultural views of time, 80/20 rule, Time wasters, setting priorities and goals.

Real World Assignment:

Write professional email on:
1. Requesting an informational interview.
2. Following up on a job application.
3. Addressing a complaint to a service provide.

Exemplary: Job applications, Professional networking, Online profiles (LinkedIn).

Learning Resources

Text Books:

1. Huckin, T. N., & Olsen, L. A. (1991). *Technical writing and professional communication (2nd Ed.)*. McGraw-Hill.
2. Ghosh, B. N. (2012). *Managing soft skills for personality development*. Tata McGraw-Hill.
3. Lesikar, R. V., & Pettit, J. D. (2019). *Report writing for business (14th Ed.)*. McGraw-Hill Education.
4. Alex, K. (2018). *Soft skills*. S. Chand & Company.

Reference Books:

1. Wallace, H. R., & Masters, L. A. (2016). *Personal development for life and work (12th Ed.)*. Cengage Learning.
2. Sharma, R. C., & Mohan, K. (2014). *Business correspondence and report writing (4th Ed.)*. Tata McGraw-Hill Education.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Technical Communication for Engineers
   https://nptel.ac.in/courses/109104031
2. NPTEL Course: Enhancing Soft Skills and Personality
   https://nptel.ac.in/courses/109107121
3. NPTEL Course: Developing Soft Skills and Personality
   https://nptel.ac.in/courses/109106094
4. Coursera Course: Business Writing
   https://www.coursera.org/learn/writing-for-business

Term Work Evaluation
The student must complete the following activity for their Term Work Journal
1. Prepare targeted resume highlighting education, skills, and experiences that match the job. 2. Draft a formal email to employer/HR inquiring about job opportunities, or information about an internship. 3. Create an optimized LinkedIn profile to enhance career opportunities, networking, and personal branding. 4. Perform role plays for conducting a corporate interview for recruitment. 5. Prepare & present a PPT on any technical topic. 6. Perform a mock pitch to investors. 7. Prepare a technical report on research activities /industrial visits/case study. 8. Simulate a team project meeting (e.g., for a college event or class activity). Assign roles and have students write a formal agenda before and minutes of meeting after, including action items and responsibilities. 9. Interview a working professional about their company's culture of integrity and accountability, and present how these ethics translate into their daily work habits and time management. 10. Prepare a "24-Hour Challenge" that students must plan of a "perfectly productive day", balancing academic tasks (e.g., studying, assignments), personal care (meals, exercise, sleep) and Leisure/hobbies.

Savitribai Phule Pune University
Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised

HSSM-283-RAI: Entrepreneurship Essentials

Teaching Scheme		Credit	Examination Scheme	
Theory	**2 Hour/Week**	**1**	**CCE**	**50 Marks**
Practical	**NA**		**End-Semester**	**NA**

Prerequisite:

Design Thinking and Idea Lab (VSE-102),
Entrepreneurship Development & Innovation (HSSM-232-RAI)

Course Objectives:

The student will be able

1. To evaluate and select appropriate funding sources (VC, angel investment, grants, etc.) for different startup stages and industries.
2. To develop compelling investor pitch decks, grant proposals, and business plans tailored to specific funder requirements.
3. To design and execute effective entrepreneurial sales strategies, including value proposition development and channel sales frameworks.
4. To analyze startup growth stages and implement suitable HR practices for each phase of organizational development.
5. To identify the legal, tax, and compliance implications of accepting different types of funding and grants.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: DESCRIBE the key sources of funding for entrepreneurs, including venture capital, angel investment, grants, crowdfunding, and bootstrapping, and their suitability for different venture stages.

CO2: DEVELOP investor-ready materials (pitch decks, business plans, grant proposals) tailored to specific funder requirements and evaluation criteria.

CO3: DEMONSTRATE entrepreneurial selling techniques, including value proposition design, cold calling, and channel sales strategies, through simulated exercises.

CO4: ANALYZE startup growth stages (idea to exit) and design stage-appropriate HR practices, contrasting startup and corporate HR models.

CO5: IDENTIFY government support schemes (e.g., Startup India, MUDRA) and apply funding negotiation strategies in simulated investment scenarios.

<table>
<tr><th colspan="3">Course Contents</th></tr>
<tr><th>Unit I</th><th>Starting the Venture and Financial Planning</th><th>(06 Hours)</th></tr>
<tr><td colspan="3">Generating Business Idea: Sources of new ideas, Methods of generating ideas, Opportunity recognition, and Environmental scanning, Competitor and industry analysis.
Feasibility Study: Market feasibility, Technical/Operational feasibility, Financial feasibility.
Business Plan: Drawing business plan, Preparing project report, Presenting business plan to investors, Marketing plan, Organizational plan.
Financial Plan: Cash budget, Working capital, Break even analysis, Debt or Equity financing, Commercial banks, Venture capital, Financial institutions Supporting entrepreneurs.</td></tr>
<tr><td colspan="3">Real World Assignment:
1. Analyze market, operational, and financial feasibility for any startup (e.g., Blinkit, Zepto, Meesho, etc.).
2. Prepare a feasibility report with charts including supply chain, tech, manpower, revenue model.
3. Design a 10-min pitch deck & perform a mock pitch to investors.</td></tr>
<tr><td colspan="3">Exemplary: Innovative challenge/competitions for young entrepreneurs are HULT Prize India (Student Entrepreneurs), NASSCOM DeepTech Club 4.0, National Startup Awards (by Startup India), etc.</td></tr>
<tr><th>Unit II</th><th>Entrepreneurial Selling</th><th>(06 Hours)</th></tr>
<tr><td colspan="3">Fundamental of Selling: Value proposition, Target market, Customer profile, Difference between entrepreneurial selling Vs professional selling.
Selling Process: Framework for accessing channel sales, Selling process - Customer’s perspective, sales pitch, cold calling.
Strategic Selling Essentials: Telling the right story, Contextualize your venture, Connecting with decision-making, Define sales metrics and developing complete sales tool kit technology.</td></tr>
<tr><td colspan="3">Real World Assignment:
1. Interview 5 potential customers from your target market and present your product/service value proposition. Record their feedback and refine your pitch based on their pain points.
2. Define your ideal customer profile (industry, role, pain points). Then, create a cold call script and practice it with a peer. Make 3 real cold calls (B2B/B2C) and document responses.
3. Pick a product (e.g., SaaS tool, physical goods) and design a channel sales strategy (distributors, affiliates, etc.). Map out 3 potential partners and outline incentives for them.</td></tr>
<tr><td colspan="3">Exemplary: Y Combinator’s Startup Pitch Day, HubSpot’s "Cold Call Olympics", Amazon’s "Working Backwards" Workshop, Coca-Cola’s Distributor Challenge, Shark Tank India vs. Corporate Sales.</td></tr>
<tr><th>Unit III</th><th>Lifecycle and Human Resource Management in Startup</th><th>(06 Hours)</th></tr>
<tr><td colspan="3">Startup Growth Stages: Concept/Idea stage, Pre-Seed/Validation, Seed/Early stage, Growth Stage/Scaling stage, Maturity/Exit/IPO/M&A stage.
Human Resource Management: Economic Environment and Start-ups, Difference between HRM for Start-ups and large corporations; Role of HRM practices in Start-ups, Best HR practices in Start-ups, Difficulties in adopting HR practices in start-ups, Evolution of HR practices in start-ups.</td></tr>
</table>

Real World Assignment:

1. Assume you're a seed-funded startup CEO. Define roles, skills needed, and compensation for your first 5 hires. Justify why each role is critical.
2. Compare HR policies (leave, remote work, performance reviews) of a startup (e.g., Canva) vs. a corporation (e.g., TCS). Present which policies scale best.
3. Analyze a real startup's HR crisis (e.g., high attrition, poor culture). Propose 3 low-cost HR solutions (e.g., mentorship, ESOPs, flexible work).

Exemplary: Andreessen Horowitz (a16z), Zappos, Shopify, LinkedIn Glint.

Unit IV	Funding & Grant Schemes	(06 Hours)

Types of Funding: Seed Stage, Stages of Funding - Seed Funding/Series A/B/C/D/E.
Type of Investors: Angels, VC's, Family offices, Corporates.
Govt. Support for Startups: Schemes and functions of directorate of industries, District Industries Centers (DICS), Industrial Development Corporation (IDC), State Financial Corporation (SFCS), Small Scale Industries Development Corporations (SSIDC), Khadi and Village Industries Commission (KVIC), Technical Consultancy Organization (TCO), Small Industries Service Institute (SISI), Recent Initiatives From MUDRA.

Real World Assignment:

1. Study a funding strategy case study for any successful startup e.g. Ola, Swiggy, Zepto, etc.
2. Role-play a seed round negotiation to experience early-stage fundraising.
3. List down any one govt./private funding scheme for young entrepreneur on sustainable development.

Exemplary: Eminent startup schemes in India includes Tata Social Enterprise Challenge, Google for Startups Accelerator, Startup India Seed Fund Scheme (SISFS), etc.

Learning Resources

Text Books:

1. Hisrich, R. D., Peters, M. P., & Shepherd, D. A. (2017). *Entrepreneurship (10th Ed.)*. Tata McGraw-Hill.
2. Charantimath, P. M. (2017). *Entrepreneurship development and small business enterprises (3rd Ed.)*. Pearson Education.
3. Angadi, V. B., Cheema, H. S., & Das, M. R. (2009). *Entrepreneurship, growth and economic integration: A linkage*. Himalaya Publishing House Pvt. Ltd.

Reference Books:

1. Barringer, B. R. (2011). *Entrepreneurship: Successfully launching new ventures (3rd Ed.)*. Pearson.
2. Bessant, J., & Tidd, J. (2011). *Innovation and entrepreneurship (2nd Ed.)*. John Wiley & Sons.
3. Desai, V. (2011). *Small scale industries and entrepreneurship*. Himalaya Publishing House.
4. Kuratko, D. F. (2014). *Entrepreneurship: Theory, process and practice (9th Ed.)*. Cengage Learning.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Entrepreneurship Essentials
   https://nptel.ac.in/courses/127105007
2. NPTEL Course: Innovation, Business Models and Entrepreneurship
   https://nptel.ac.in/courses/110107094
3. Coursera Course: Essentials of Entrepreneurship: Thinking & Action
   https://www.coursera.org/learn/entrepreneurial-thinking

Savitribai Phule Pune University Second Year of Robotics and Artificial Intelligence (2024 Pattern) Revised				
VEC-284-RAI: Constitution of India and Universal Human Values				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**2 Hours/Week**	**2**	**CCE**	**20 Marks**
Practical	**NA**		**End-Semester**	**30 Marks**

Prerequisite:

Nil

Course Objectives:

The students will be able

1. To instill core human values like truth, peace, and non-violence.
2. To promote understanding of constitutional principles in daily life.
3. To encourage ethical decision making and self-discipline.
4. To align personal conduct with social and national responsibilities.
5. To nurture responsible, value-driven citizens and leaders.

Course Outcomes:

On completion of the course, learner will be able to:

CO1: **UNDERSTAND** the basis of law, the concept 'Constitution' and the interpretation of the Preamble.

CO2: **DEFINE** the basis of governance of the nation and the fundamental rights and illustrate the functioning of the union and the state executive.

CO3: **OUTLINE** the aspects that allow the use of rights to fulfill one's duties as a responsible citizen.

CO4: **ANALYZE** the moral and ethical character needed for a professional engineer.

CO5: **CLASSIFY** law and ethics for universal human values.

Course Contents

Unit I	Foundation of the Indian Constitution	(06 Hours)

Introduction to the Constitution of India: Historical Background, Objectives, and Salient Features.
Preamble to the Constitution: Meaning, Significance, and Key Terms (Justice, Liberty, Equality, Fraternity).
Basic Concepts: Rule of Law, Human Rights, and Fundamental Rights.

Real World Assignment:

1. Simulate a Constituent Assembly debate where students draft a preamble for a hypothetical new state, justifying their choice of key values (Justice, Liberty, Equality, Fraternity) in response to a given social crisis.
2. Conduct a mock trial or public hearing where students apply the principle of Rule of Law to decide a citizen's grievance, balancing it against competing claims of human rights in a realistic scenario.
3. Design and present a community awareness campaign (poster, street play, or social media plan) that educates citizens about a specific Fundamental Right and the procedure to claim it when violated.

Exemplary: Students create a street play on Right to Education (Article 21A), showing a child denied admission, parents approaching the school, then filing complaint with the State Commission for Protection of Child Rights, ending with a legal victory.

Unit II	Fundamental Rights, Duties and Directive Principles	(06 Hours)

Fundamental Rights (Part-III): Detailed study of Rights (Articles 12-35), Limitations, Landmark Cases.
Fundamental Duties: List, Significance, and Enforceability.
Directive Principles of State Policy (DPSP): Relevance, Conflict with Fundamental Rights, and Implementation.

Real World Assignment:

1. Create a citizen's charter or complaint diary that documents five common violations of Fundamental Duties in daily life, along with proposed non-legal measures to promote their observance, and to debate their enforceability in a classroom parliament.
2. Conduct a moot court simulation where students argue a landmark Fundamental Rights case, presenting petitions from both sides and delivering a judicial ruling that interprets specific Articles (12-35) and their limitations.
3. Prepare a "State Policy Report Card" grading a chosen state government on implementation of three DPSPs (e.g., Article 39, 43, 48) with evidence and recommendations.
4. Organize a legislative assembly simulation where students draft a bill that must balance a Directive Principle with a conflicting Fundamental Right, justifying their choices through constitutional interpretation and debate.

Exemplary: Students simulate Kesavananda Bharati case. Petitioners argue Parliament cannot alter basic structure (violates Article 13, 14, 19, 21). Respondents argue parliamentary sovereignty. Judges deliver ruling upholding basic structure doctrine, limiting amendment power under Article 368.

Unit III	Governance and Electoral Process in India	(06 Hours)

Organs of the State: Legislative, Executive, and Judiciary (Structure at Union and State levels).
Prerogative Writs: Types (Habeas Corpus, Mandamus, etc.) and their role in enforcing rights.
Electoral Procedure in India: Election Commission, Voting Process, and Electoral Reforms.

Real World Assignment:

1. Create a flowchart showing the structure and functions of the Legislative, Executive, and Judiciary at Union and State levels, with one example of checks and balances.
2. Role-play a writ petition hearing where students draft and present one type of prerogative writ for a given violation of rights.
3. Conduct a mock election in class, including voter registration, polling, counting, and proposing two electoral reforms based on the experience.

Exemplary: A student creates a flowchart with: President (Executive) appoints CJI; Judiciary reviews laws passed by Parliament (Legislative); Parliament impeaches judges; with a case example of the NJAC judgment where Judiciary struck down a Parliamentary amendment.

Unit IV	Special Provisions, Amendments, and Ethics	(06 Hours)

Constitutional Safeguards: Provisions for SCs, STs, OBCs, Women, and Children.
Emergency Provisions & Amendment Procedure: Types of Emergencies, Important Amendments (E.G., 42nd, 44th).
Law, Ethics, and Professional Values: Relationship between Law and Ethics, Professional Ethics for Engineers, Universal Human Values.

Real World Assignment:

1. Create a constitutional safeguards wall chart/map showing provisions for SCs, STs, OBCs, Women, and Children with real-life implementation examples.
2. Prepare a case study presentation on a landmark constitutional amendment (42nd or 44th), analyzing its changes and impact.
3. Conduct a parliamentary debate on a constitutional amendment bill where students argue safeguarding special provisions, emergency powers, and ethical considerations.

Exemplary: Students simulate Parliament debating a bill to remove reservation for OBCs in higher education. One group defends (citing efficiency), another opposes (citing social justice, Articles 15(4), 16(4)), and ethics committee argues fairness and equality, finally voting on the bill.

Learning Resources

Text Books:

1. Basu, D. D. (2018). *Introduction to the Constitution of India (19th/20th Ed.)*. Prentice-Hall EEE.
2. Suresh, J., & Raghavan, B. S. (2016). *Human values and professional ethics*. S. Chand & Company Pvt. Ltd.
3. Harris, C. E., Pritchard, M. S., & Robins, M. J. (2018). *Engineering ethics*. Thompson Asia.
4. Pylee, M. V. (2004). *An introduction to Constitution of India*. Vikas Publishing House Pvt. Ltd.
5. Gogate, S. B. (2011). *Human values & professional ethics*. Vikas Publishing House Pvt. Ltd.

MOOC / NPTEL/YouTube Links:

1. NPTEL Course: Constitution Law and Public Administration in India
   https://onlinecourses.nptel.ac.in/noc24_lw05/preview

2. NPTEL Course: Introduction to Indian Constitution
   https://onlinecourses.swayam2.ac.in/e-learning/preview/imb26_mg151

3. NPTEL Course: Constitutional Studies
   https://onlinecourses.nptel.ac.in/e-learning/preview/noc20_lw03

Task Force for Curriculum Design and Development

Advisors & the Chairmen - Board of Studies

Dr. P. A. Patil	Dr. Kushare Prashant
Dr. Ravindra Navthar	Dr. Girish Modak
Dr. Amar Pandhare	Dr. Shiv Sai Dixit
Dr. Vishnu Wakchaure	Dr. Niranjan Kolhe
Dr. S. B. Zope	Dr. Ajit Bhosale
Dr. J. A. Hole	Dr. Narendra Deore
Dr. Mohan Khond	Dr. V. N. Chougule
Dr. A. B. Gawand	

Team Members for Course Design

Dr. Amol S. Bhanage

Dr. Nilesh N. Satonkar

Prof. Nilesh C. Dhobale

Prof. Shilpa N. Tambe

Compiled By

Dr. Amol S. Bhanage

Chairman

Dr. Pradeep A. Patil

Chairman– Board of Studies
Mechanical Engineering
Savitribai Phule Pune University, Pune

Dean

Dr. Raosaheb Latpate

Dean– Science and Technology

Savitribai Phule Pune University, Pune