Savitribai Phule Pune University
Faculty of Science and Technology

Curriculum/Syllabus
For
Third Year
Bachelor of Engineering
(Choice Based Credit System)
Automation and Robotics
(2019 Course)
Board of Studies – Mechanical and Automobile Engineering
(With Effect from Academic Year 2022-23)

Savitribai Phule Pune University
Board of Studies - Mechanical and Automobile Engineering
Undergraduate Program - Automation and Robotics (2019 pattern)

Course Code	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credit			
		TH	PR	TUT	ISE	ESE	TW	PR	OR	TOTAL	TH	PR	TUT	TOTAL
Semester-V														
302521	Design of Robot Elements	3	2	--	30	70	--	--	25	125	3	1	--	4
302522	Robot Kinematics and Dynamics	3	2	--	30	70	--	50	--	150	3	1	--	4
302523	Computer Aided Engineering and Manufacturing	3	2	--	30	70	--	50	--	150	3	1	--	4
302524	Signal Processing and Conditioning	3	2	--	30	70	25	--	--	125	3	1	--	4
302525	Elective-I	3	--	--	30	70	--	--	--	100	3	--	--	3
302526	Robot Programming Laboratory	--	2	--	--	--	25	--	--	25	--	1	--	1
302047	Skill Development	--	2	--	--	--	25	--	--	25	--	1	--	1
302048	Audit Course-V[$]	--	--	--	--	--	--	--	--	--	--	--	--	--
		15	**12**	**--**	**150**	**350**	**75**	**100**	**25**	**700**	**15**	**5**	**1**	**21**
Semester-VI														
302527	Sensors and Vision Systems in Robots	3	2	--	30	70	--	50		150	3	1	--	4
302528	Artificial Intelligence in Robots	3	2	--	30	70	--	50	--	150	3	1	--	4
302529	Modelling and Simulation	3	2	--	30	70	--	50	--	150	3	1	--	4
302530	Elective-II	3	--	--	30	70	--	--	--	100	3	--	--	3
302531	Metrology and Quality Control in Automation	--	2	--	--	--	25	--	--	25	--	1	--	1
302532	Computer Aided Digital Manufacturing Laboratory	--	2	--	--	--	25	--	--	25	--	1	--	1
302055	Internship/Mini Project*	--	4	--	--	--	100	--	--	100	--	4	--	4
302056	Audit Course-VI[$]	--	--	--	--	--	--	--	--	--	--	--	--	--
		12	**14**	**--**	**120**	**280**	**150**	**150**	**--**	**700**	**12**	**9**	**--**	**21**

Elective-I		Elective-II	
302525-A	Advanced Forming and Joining Processes	302530-A	Machining Science and Technology
302525-B	Optimization Techniques	302530-B	Maintenance and Safety Engineering

Abbreviations: TH: Theory, **PR**: Practical, **TUT**: Tutorial, **ISE**: In-Semester Exam, **ESE**: End-Semester Exam, **TW**: Term Work, **OR**: Oral

*Internship is to be completed after semester 5 and before commencement of semester 6 of at least 4 to 6 weeks; and it is to be assessed and evaluated in semester 6.

Instructions:

- Practical/Tutorial must be conducted in FOUR batches per division only.
- Minimum number of Experiments/Assignments in PR/Tutorial shall be carried out **as mentioned in the syllabi** of respective courses.
- Assessment of tutorial work has to be carried out similar to term-work. The Grade cum marks for Tutorial and Term-work shall be awarded on the basis of **continuous evaluation.**

Note: Interested students of TE (Automation and Robotics) can opt for any one of the audit course from the list of audit courses prescribed by BOS (Mechanical and Automobile Engineering)

$ Audit course is mandatory but non-credit course. Examination has to be conducted at the end of Semesters for award of grade at institute level. Grade awarded for audit course shall not be calculated for grade point and CGPA

302521: Design of Robot Elements					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	3	**In-Semester**	30 Marks
Practical	02 Hr./Week	**Practical**	1	**End-Semester**	70 Marks
				Oral	25 Marks

Prerequisites: Material Science, Solid Mechanics, Roots of Equations, Interpolation Techniques, Kinematics of Mechanisms

Course Objectives:

1. UNDERSTAND the various design considerations for robots and automation systems, design procedure and select materials for a specific application
2. CALCULATE the stresses in robot arm components due to various types of loads and failure
3. ANALYZE robotic arm components subjected to variable loading for finite and infinite life
4. DESIGN of basic components of robots and automation viz. shafts, gear boxes, bearings, belts, etc.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: UNDERSTAND design philosophy for basic components of the system
CO2: USE design considerations for designing components under fluctuating loads
CO3: DESIGN basic machine elements viz. shafts, clutches, brakes, etc.
CO4: SELECT and DESIGN robot end-effector as per the applications
CO5: UNDERSTAND power transmission devices and SELECT appropriate tool for power transmission
CO6: SELECT appropriate type of bearings for Robotic applications based on operating speed, loads, etc.

Course Contents

Unit 1	**Design of Simple Machine components under static load**

Introduction, Modes of failures, Factor of safety, Theories of failures, Selection of Factor of Safety, Service factor, Design of joints - Cotter joint, Knuckle joint, Design of levers - lever for safety valve, bell crank lever, Design of components subjected to eccentric loading, Design of joints – Welded joints, Riveted joints.

Unit 2	**Design against fluctuating loads**

Stress concentration and its factors, Reduction of stress concentration factors, fluctuating stresses, fatigue failures, endurance limit, S-N curve, Notch sensitivity, Endurance limit, Endurance strength modifying factors, Reversed stresses – Design for Finite and Infinite life, Cumulative damage in fatigue failure, Soderberg, Gerber, Goodman Lines, Modified Goodman diagrams, Fatigue design under combined stresses (Theoretical treatment only).

Unit 3	**Design of basic machine components**

Shaft design on the Strength basis, torsional rigidity basis and lateral rigidity basis, Design of shaft as per ASME code.

Belt drive - geometrical relation, analysis of belt tensions, condition for maximum power,

characteristics of belt drives, selection of flat belts, Selection of V-Belts.

Chain drive - geometrical relation, polygonal effect, power rating of roller chain, design of chain drive.

Unit 4	**Design of Robot End Effectors**

Introduction, Type of End-effectors, Considerations for Gripper selection and design, Design Mechanical grippers, Other types of grippers, Tools as an End effector, The robot and end effector interface, Physical support of the end effector.

Unit 5	**Design of Machine Tool Gearboxes**

Introduction, Classification of gears – Spur, Helical, Bevel, Worm and Worm Wheel, Applications of gears, Material selection for gears, Modes of gear tooth failure, Gear Lubrication Methods.

Introduction to Machine Tool Gearboxes, classification, basic considerations in design of drives and its Applications, Determination of variable speed range, Graphical representation of speed and structure diagram, Ray diagram, selection of optimum ray diagram, Kinematic/Gearing Diagram, Deviation diagram, Difference between numbers of teeth of successive gears in a change gear box.

Unit 6	**Sliding and Rolling Contact Bearing**

Sliding contact bearing: Introduction to sliding contact bearing, classification, Reynolds's equation (2D), Petroff's equations, Sommerfeld number, Parameters of bearing design.

Rolling Contact Bearings: Types of rolling contact Bearings and its selection, Static and dynamic load carrying capacities, Stribeck's Equation, Equivalent bearing load, Load-life relationship, Selection of bearing life, Selection of rolling contact bearings from manufacturer's catalogue, Design for cyclic loads, Types of failure in rolling contact bearings - causes and remedies.

Books and other resources

Text Books:

1. Bhandari V.B, Design of Machine Elements, Tata McGraw Hill Publication Co. Ltd.
2. Machine Design by Pandya and Shah, Charotar Publishing
3. Shigley J.E. and Mischke C.R., Mechanical Engineering Design, McGraw Hill Publication Co. ltd.

References Books:

1. Design Data - P.S.G. College of Technology, Coimbatore.
2. Spotts M.F. and Shoup T.E., Design of Machine Elements, Prentice Hall International.
3. P. Kannaiah, Design of Transmission systems, SCIETCH Publications Pvt Ltd.

Web References:

Links for online NPTEL/SWAYAM courses:
https://nptel.ac.in/courses/112/105/112105124/, Design of Machine Elements, IIT Kharagpur
https://nptel.ac.in/courses/112/106/112106137/ - Machine Design-II, IIT Madras

Term Work

The student shall complete the following activity as a Term Work (Any 5 from 1 to 6 and 7 is compulsory):

1. Design of lever subjected to static/fluctuating loads
2. Design of riveted/welded joint
3. Design of shaft using ASME code
4. Design/Selection of Gear Box for suitable application
5. Design of rolling contact bearings
6. Design of Gripper / End effector (Compulsory)
7. Design of Robotic Arm (Compulsory)

   A Design Project to develop and apply the knowledge of design using Design and drafting software for any Robotic arm / Automation system on the basis of:

   i. Idea generation,

ii. Creativity, Reliability and safety,
iii. Design parts of the system
iv. Ergonomic Considerations
v. Use of International standards

Projects shall be in the form of design of mechanical systems on multi speed spindle gear box including design of belt and pulley, Prime mover selection etc. The design project shall consist of two full imperial (A1) size sheets involving assembly drawing with a part list and overall dimensions and drawings of individual components. Manufacturing tolerances, surface finish symbols and geometric tolerances should be specified for important surfaces. A design report giving all necessary calculations of the design of components and assembly should be submitted in a separate file. Design data book shall be used wherever necessary to achieve selection of standard components.

302522: Robot Kinematics and Dynamics					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	3	**In-Semester**	30 Marks
Practical	02 Hr./Week	**Practical**	1	**End-Semester**	70 Marks
				Practical	50 Marks

Prerequisites: Solid Mechanics, Kinematics of Mechanisms

Course Objectives:

1. To control both the position and orientation of the tool in the three dimensional space.
2. The relationship between the joint variables and the position and the orientation of the tool.
3. Planning trajectories for the tool to follow on order to perform meaningful tasks.
4. To precisely control the high speed motion of the system

Course Outcomes:

On completion of the course the learner will be able to;
CO1: UNDERSTAND the coordinate system used in robotics
CO2: USE link coordinates to decide the position of end effectors or tool
CO3: DESIGN the system with understanding and application of coordinate system
CO4: SELECT and UNDERSTAND work envelope of robot and its trajectory planning
CO5: UNDERSTAND the dynamics of manipulator for design of robot
CO6: UNDERSTAND the functions of control hardware and its architecture

Course Contents

Unit 1	**Transformations**

Introduction, position and orientation of objects, objects coordinate frame Rotation matrix, Euler angles Roll, pitch and yaw angles coordinate Transformations, Joint variables and position of end effector, Dot and cross products, coordinate frames, Rotations, Homogeneous coordinates.

Unit 2	**Direct Kinematics**

Link coordinates D-H Representation, The ARM equation. Direct kinematic analysis for Four axis, SCARA Robot and three, five and six axis Articulated Robots.

Unit 3	**Inverse Kinematics**

The inverse kinematics problem, General properties of solutions. Tool configuration, Inverse kinematics of four axis SCARA robot and three and five axis, Articulated robot.

Unit 4	**Workspace Analysis and Trajectory Planning**

Workspace Analysis, work envelope of a Four axis SCARA robot and five axis articulated robot workspace fixtures, the pick and place operations, Joint space technique - continuous path motion, Interpolated motion, straight line motion and Cartesian space technique in trajectory planning.

Unit 5	**Manipulator Dynamics**

Introduction, Lagrange's equation kinetic and potential energy. Link inertia Tensor, link Jacobian Manipulator inertia tensor. Gravity, Generalized forces, Lagrange-Euler Dynamic model, Dynamic model of a Two-axis planar robot, Newton Euler formulation, Lagrange Euler formulation, problems.

Unit 6	**Control Hardware**

Control considerations, Hardware architecture, Hardware for Joint Controllers, Computational Speeds.

Books and other resources

Text Books:

1. S. K. Saha, Introduction to Robotics, Second Edition, McGraw Hill Education (India) Pvt. Ltd.
2. Spong, Vydiasagar, Robot Dynamics and Control (Wiley)

References Books:

1. Robert J. Schilling, Fundamentals of Robotics Analysis and Control, PHI Learning, 2009.

2. Richard D. Klafter, Thomas .A, Chri Elewski, Michael Negin, Robotics Engineering an Integrated Approach, Phi Learning., 2009.

3. P.A. Janaki Raman, Robotics and Image Processing An Introduction, Tata Me Graw Hill Publishing company Ltd., 1995.

4. Francis N-Nagy Andras Siegler, Engineering foundation of Robotics, Prentice Hall Inc., 1987.

5. Bernard Hodges, Industrial Robotics, Second Edition, Jaico Publishing house, 1993.

6. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, MIT Press, 2003.

7. John J. Craig, Introduction to Robotics Mechanics and Control, Third Edition, Pearson, 2008.

8. Bijay K. Ghosh, Ning Xi, T.J. Tam, Control in Robotics and Automation Sensor - Based integration, Academic Press, 1999.

Guidelines for Laboratory Conduction

The student shall complete the following activity as a term work journal

*****RoboAnalyzer can be used for completion of the following laboratory work.**

Total 07 experiments from the following list must be performed. Term work of the student is evaluated based on the completion of practical, Assignments and Industrial Visits.

Practical *(Any Seven):*

1. DH Parametrer analysis for 1 DOF Robot
2. DH Parametrer analysis for 2 DOF Robot
3. DH Parametrer analysis for 3 DOF Robot
4. DH Parametrer analysis for 4 DOF Robot
5. DH Parameter analysis of SCARA Robot
6. DH Parameter analysis on Articulated Robot Manipulator.
7. Create and simulate a 3R robot in MATLAB/Sim Mechanics and verify its forward kinematics.
8. Extend the MATLAB/Sim Mechanics model to verify analytical inverse kinematics solution.
9. Use MATLAB/Sim Mechanics to perform inverse and forward dynamics of a 2R planar robot.
10. Industrial visits to provide awareness and understanding of the course – student must submit a properly documented industrial visit report.

302523: Computer Aided Engineering and Manufacturing					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	3	**In-Semester**	30 Marks
Practical	02 Hr./Week	**Practical**	1	**End-Semester**	70 Marks
				Practical	50 Marks

Prerequisites: Solid Mechanics, Kinematics of Mechanisms and Design software.

Course Objectives:

1. UNDERSTAND the basic concepts of Computer Aided Engineering (CAE) and CHARACTERISTICS of various elements required for analysis.
2. UNDERSTAND the approaches of Finite Element Method (FEM) and to find displacement and stresses over the body.
3. APPLY computational technique to solve complex solid mechanics problems and its loading states using CAE tools.
4. UNDERSTAND role of Computer Aided Manufacturing
5. To create awareness regarding lean manufacturing concepts.
6. To impart knowhow of process planning and costing of different processes.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: DEFINE the use of CAE tools and DESCRIBE the significance of shape functions infinite element formulations.

CO2: APPLY material properties and boundary condition to SOLVE 1-D and 2-D element stiffness matrices to obtain nodal or elemental solution.

CO3: ANALYZE and APPLY various numerical methods for different types of analysis.

CO4: CREATE process plan and GENERATE GandM code using CAM software tools.

CO5: UNDRSTAND lean manufacturing tools and techniques

CO6: APPLY knowledge to do process planning and ESTIAMTE costing for the same.

Course Contents

Unit 1 **Introduction to Computer Aided Engineering (CAE)**

Introduction, Use of CAE in Product development, Discretization methods – Finite Element Method (FEM), Finite Difference Method (FDM) and Finite Volume Method (FVM), CAE Tools- Pre-processor, Solver and Post-Processor.

Element Shapes – 1D, 2D and 3D elements, Nodal Unknowns and field variables, Coordinate Systems, Shape Functions- linear, quadratic and cubic, Convergence Requirements of Shape Functions.

Meshing Techniques- Discretization of a Structure, 1D, 2D and 3D element Meshing, Element selection criteria, Refining Mesh, Effect of mesh density in critical region, Use of Symmetry.

Unit 2 **1D Finite Element Analysis**

Consistent Unit System, Introduction to approaches used in Finite Element Analysis (FEA) such as direct approach and energy approach. Bar and Truss Element - Element stiffness matrix, Assembling stiffness Equation, Load vector, stress and reaction forces calculations. Temperature effect on Bar Element- Calculation due to uniform temperature change, Stress and reaction forces calculations.

Unit 3	2D Finite Element Analysis
Plane Stress-Strain, axisymmetric problems in 2D elasticity. Constant Strain Triangle (CST) - Element Stiffness matrix, Assembling stiffness equation, Load vector, Stress and reaction forces calculations. Post Processing Techniques – Check and validate accuracy of results, Average and Un-average stresses, and special tricks for Post Processing. Interpretation of results and design modifications, CAE reports.	
Unit 4	**Computer Aided Manufacturing**
Introduction, Coordinate system, Working principal of CNC Lathe, Turning Centers, Milling Machine, Steps in developing CNC part program, Tool and geometric compensations, subroutine and Do loop using canned cycle. Case study – G and M code, Machining of component with Speed (m/min), Feed (mm/rev or mm/min) and Depth of Cut (mm) **Digital Manufacturing -** Basic Terms, Industry 4.0, Intelligent Machining.	
Unit 5	**Lean Manufacturing**
Conventional Manufacturing versus Lean Manufacturing, Principles of Lean Manufacturing, Basic elements of lean manufacturing, Introduction to LM Tools, Cellular Manufacturing, Types of Layout, Principles of Cell layout, Implementation, Just in Time (JIT), Principles of JIT and Implementation of Kanban, Pillars of Total Productive Maintenance (TPM), Principles and implementation of TPM. Six Sigma: Tools, Techniques and Methodology.	
Unit 6	**Process Planning and Cost Estimation**
Process Planning - Introduction- methods of process planning-Drawing interpretation-Material evaluation – steps in process selection-.Production equipment and tooling selection. Process parameters calculation for various production processes. **Cost Estimation-** Importance of costing and estimation, methods of costing, elements of cost estimation, Types of estimates, Estimating procedure, Estimation labor cost, material cost, allocation of overhead charges, Calculation of depreciation cost. Basics of Production Cost Estimation and Machining Time Calculation.	

Books and other resources

Text Books:

1. Gokhale N. S., Deshpande S. S., Bedekar S. V. and Thite A. N., Practical Finite Element Analysis, Finite to Infinite, Pune, 1st Edition, 2008.
2. S. S. Bhavikatti, Finite Element Analysis, New Age International Publishers, Third Edition, 2015.
3. Chandrupatla T. R. and Belegunda A. D., Introduction to Finite Elements in Engineering, Prentice Hall India, 2002.
4. G Lakshmi Narasaiah, Finite Element Analysis, BS Publications / BSP Books, 2nd edition, 2020.
5. J. N. Reddy, An Introduction to the Finite Element Method, Mcgraw Hill Series in Mechanical, 2005.
6. P. Seshu, Text book of Finite Element Analysis, PHI Learning Private Limited, New Delhi, 10th Printing, 2012.

References Books:

1. K. J. Bathe, Finite Element Procedure, Prentice-Hall of India (P) Ltd., New Delhi, 1996.
2. Cook R. D., Finite Element Modeling for Stress Analysis, John Wiley and Sons Inc, 1995.
3. G.R. Liu S. S. Quek, The Finite Element Method- A Practical Course, Butterworth Heinemann,

2013.
4. Fagan M. J., Finite Element Analysis Theory and Practice, Harlow Pearson/Prentice Hall, 2012.
5. S. Moaveni, Finite element analysis, theory and application with Ansys, Pearson, Third Edition, 2011.
6. David V. Hutton, Fundamental of Finite Element Analysis, Tata McGraw-Hill, 2017.
7. Mukhopadhyay M and Sheikh A. H., Matrix and Finite Element Analyses of Structures, Ane Books Pvt. Ltd., 2009
8. Daryl L. Logan, A First Course in the Finite Element Method, Fourth Edition, Thomson Canada Limited, 2007.
9. O.C. Zienkiewicz, The Finite Element Method: Its Basis and Fundamentals, Sixth Edition, Elsevier Butterworth-Heinemann, 2005.
10. Koren, Y., Computer Control of Manufacturing systems, McGraw Hill (2009).
11. Suh Suk-Hwan, Kang Seong-Kyoon, Chung Dae-Hyuk, Stroud Ian., Theory and Design of CNC Systems, 2008, Springer-Verlag London Limited
12. Smith Peter, CNC programming handbook, 2nd edition, 2003, Industrial Press Inc.
13. Groover, M. P. and Zimmers, E. W., CAD/CAM: Computer Aided Design and Manufacturing, 2006, Pearson Education India
14. Hood-Daniel P., and Kelly J.F., Build Your Own CNC Machine, 2009, Springer-Verlag New York 6. Manuals of CAD/CAM Software Package on CAM Module and CNC Machines.

Web References:

1. https://nptel.ac.in/courses/112/104/112104116/-for Basics of Finite Element Analysis by Prof. Nachiketa Tiwari, IIT Kanpur
2. https://nptel.ac.in/courses/112/106/112106130/for Advanced Finite Element Analysis by Dr. R. Krishna kumar, Department of Mechanical Engineering, IIT Madras
3. https://nptel.ac.in/courses/112/103/112103299/for Finite Element Analysis for Welding Analysis by Prof. Swarup Bag, Department of Mechanical Engineering, IIT Guwahati.
4. https://sites.ualberta.ca/~wmoussa/AnsysTutorial/ for ANSYS Tutorials

Term Work

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

Practical: The student shall complete the following practical in laboratory using suitable ANSYS or any other analysis software:

1. 1D Bar Element – Structural Linear Analysis
2. Truss Analysis using 1D Element
3. Plate/Shell Element – Structural Linear and Non-Linear Analysis **OR** Beam Element – Non-Linear Buckling Analysis
4. Thermal Analysis – Static/Transient Analysis **OR** Coupled Analysis- (Structural + Thermal)
5. Analysis of Machine Component using 3D Elements
6. Non-Linear Analysis of Assembly using Contact Elements **OR** Modal Analysis – Spring - Mass system, simply supported/Cantilever beam, etc.
7. Complete analysis of any 3D model based on industrial robots.

302524: Signal Processing and Conditioning					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	3	**In-Semester**	30 Marks
Practical	02 Hr./Week	**Practical**	1	**End-Semester**	70 Marks
				Term Work	25 Marks

Prerequisites: Basics of Electrical components, Binary to Decimal Conversion, Data communication Module, Op amp Circuits, Linear Algebra, Laplace Transformation method, Logic gates.

Course Objectives:

1. UNDERSTAND the key elements of mechatronics, principle of sensor and its characteristics.
2. UNDERSTAND the concept of signal processing and use of interfacing systems such as ADC, DAC, Digital I/O
3. UNDERSTAND the block diagram representation and concept of transfer function
4. UNDERSTAND the system modeling and analysis in frequency domain
5. UNDERSTAND the system modeling and analysis in time domain, controller modes and its industrial applications
6. UTILIZE the concepts of PLC system and its ladder programming and significance of PLC system in industrial application

Course Outcomes: On completion of the course the learner will be able to:

CO1: DEFINE key elements of mechatronics, principle of sensor and its characteristics.
CO2: UTILIZE concept of signal processing and MAKE use of interfacing systems such as ADC, DAC, Digital I/O.
CO3: DETERMINE the transfer function by using block diagram reduction technique.
CO4: EVALUATE Poles and Zero, frequency domain parameter for mathematical modeling for mechanical system.
CO5: APPLY the concept of different controller modes to an industrial application.
CO6: DEVELOP the ladder programming for industrial application

Course Contents

Unit 1	**Sensors and Actuators**

Introduction to Robot and its Applications; Measurement Characteristics: Static and Dynamic;
Sensors: Types of sensors; Motion Sensors – Encoder (Absolute and incremental), Lidar, Eddy Current, Proximity (Optical, Inductive, Capacitive), MEMS Accelerometer.
Temperature sensor – Pyrometer, Infrared Thermometer; Force / Pressure Sensors – Strain gauges, Piezoelectric sensor; Flow sensors – Electromagnetic, Ultrasonic, Hot-wire anemometer; Color sensor – RGB type; Biosensors – Enzyme, ECG, EMG.
Actuators: Servo motor; Hydraulic and Pneumatic (must be restricted to classification and working of one type of linear and rotary actuator); linear electrical actuators; Selection of Sensor and Actuator.

Unit 2	**Block Diagram Representation**

Introduction to Mechatronic System Design; Identification of key elements of Mechatronics systems and represent into Block Diagram; Open and Closed loop Control System; Concept of Transfer Function; Block Diagram and Reduction principles; Applications of Automation and Robotics: Household, Automotive, Industrial shop floor.
Transfer Function based modeling of Mechanical, Thermal and Fluid system; Concept of Poles and Zeros;

Pole zero plot, Stability Analysis using Routh Hurwitz Criterion (Numerical Approach)

Unit 3	**Data Acquisition**

Introduction to Signal Communication and Types-Synchronous, Asynchronous, Serial, Parallel; Bit width, Sampling theorem, Aliasing, Sample and hold circuit, Sampling frequency; Interfacing of Sensors / Actuators to Data Acquisition system; 4 bit Successive Approximation type ADC; 4 bit R- 2R type DAC; Current and Voltage Amplifier.

Unit 4	**Programmable Logic Control (PLC)**

Introduction to PLC; Architecture of PLC; Selection of PLC; Ladder Logic programming for different types of logic gates; Latching; Timers, Counters; PLC control of Hydraulics / Pneumatics / Mechatronics systems involving timing and counting operations., Practical examples of Ladder Programming.

Unit 5	**Time and Frequency Domain Analysis**

Time Domain Analysis – Unit step Response analysis via Transient response specifications (Percentage overshoot, Rise time, Delay time, Steady state error etc.)

Frequency Domain Analysis – Frequency Domain Parameters - Natural Frequency, Damping Frequency and Damping Factor; Mapping of Pole Zero plot with damping factor, natural frequency and unit step response ; Introduction to Bode Plot, Gain Margin, Phase Margin

Unit 6	**Control Systems**

Proportional (P), Integral (I) and Derivative (D) control actions; PI, PD and PID control systems in parallel form; Unit step Response analysis via Transient response specifications: Percentage overshoot, Rise time, Delay time, Steady state error; Manual tuning of PID control; Linear Quadratic Control (LQR).

Books and other resources

Text Books:

1. K.P. Ramchandran, G.K. Vijyaraghavan, M.S. Balasundaram, Mechatronics: IntegratedMechanical Electronic Systems, Willey Publication, 2008
2. Bolton, Mechatronics - A Multidisciplinary approach, 4th Edition, Prentice Hall, 2009

References Books:

1. Proakis J G and Manolakis DG Digital Signal Processing Principles, Algorithms and Application, PHI.
2. Openheim AV and Schafer RW, Discrete Time Signal Processing PHI.
3. Samuel D Stearns, "Digital Signal Processing with examples in MATLAB," CRC Press.
4. ES Gopi. "Algorithm collections for Digital Signal Processing Applications using Matlab," Springer.
5. Taan S. Elali, "Discrete Systems and Digital Signal Processing with MATLAB" CRC Press,2005

Web References:

1. https://www.elprocus.com/what-is-a-biosensor-types-of-biosensors-and-applications/
2. https://www.elprocus.com/color-sensor-working-and-applications/
3. https://www.youtube.com/watch?v=kbjCGGTXqUoandab_channel=Controlengineering
4. https://youtu.be/clTA0pONnMs?list=PLHMDN3JFtE5wEz95H2XuzRaafK3fUsaki
5. https://nptel.ac.in/content/storage2/courses/108105063/pdf/L 12(SS)%20(IAandC)%20((EE)NPTEL).pdf
6. https://nptel.ac.in/content/storage2/courses/112104158/lecture5.pdf

Guidelines for Laboratory Conduction

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

The Term work shall consist of completion of Practical, Self-learning Study Assignments and Presentations. Oral examination shall be based on the Term work undertaken during the semester. Practical (Any one experiments out of experiment no 1 to 3 from the following list whereas experiment no. 4 to 10 are mandatory).

1. Experiment on measurement of temperature using suitable sensor.
2. Experiment on measurement of load using suitable sensor.
3. Experiment on measurement of displacement using suitable sensor.

4. Development of a data acquisition / mechatronics system using low cost open source hardware and software.
5. Experiment on interfacing of suitable sensor and actuator with DAQ.
6. Modeling and analysis of mechanical system and its verification using suitable simulation software.
7. PID control of Mechanical System using suitable simulation software and experimental verification (verification only if experimental setup is available).
8. Ladder Logic Simulation of suitable application.
9. Demonstration of PLC controlled electro hydraulic / elector pneumatic circuit. 10. Industrial visit to understand integration and application of Mechatronics.

Assignments:

1. Application of Sensors and Actuators in Health Science and Selection of Suitable Sensor and Actuator.
2. Block Diagram Representation of Feedback Control System and determination of Closed Loop Transfer Function.

302525-A: Advanced Forming and Joining Processes					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	3	**In-Semester**	30 Marks
Practical	--	**Practical**	--	**End-Semester**	70 Marks

Prerequisites: Manufacturing Processes, Engineering Materials and Metallurgy, Machine shop

Course Objectives:

1. UNDERSTAND advances in sheet metal forming operations
2. UNDERSTAND the advanced special metal forming processes.
3. UNDERSTAND weld metallurgy and weld characterization techniques.
4. UNDERSTAND and describe various advanced solid state welding processes.
5. CLASSIFY AND DESCRIBE various advanced welding processes.
6. KNOW about sustainable manufacturing and its role in manufacturing industry

Course Outcomes: On completion of the course the learner will be able to;

CO1: ANALYSE the effect of friction in metal forming deep drawing and IDENTIFICATION of surface defects and their remedies in deep drawing operations

CO2: ASSESS the parameters for special forming operation and SELECT appropriate special forming operation for particular applications

CO3: ANALYSE the effect of HAZ on microstructure and mechanical properties of materials

CO4: CLASSIFY various solid state welding process and SELECT suitable welding processes for particular applications

CO5: CLASSIFY various advanced welding process and SELECT suitable welding processes for particular applications.

CO6: INTERPRET the principles of sustainable manufacturing and its role in manufacturing industry

Course Contents

Unit 1	**Mechanics of Steel Metal Forming**

Theory of plasticity – yield criteria-work of plastic deformation- Sheet Metal Forming-Formability studies-conventional processes, Effect of friction in forming operation, Experimental techniques of evaluation of friction in metal forming, deep drawing, analysis (Numerical), surface defects identification and remedies, introduction to Forming simulation, Challenges in Forming.

Unit 2	**Special Forming Processes**

HVF, HERF (Explosive Forming) techniques- super plastic forming techniques-Hydro forming-Stretch forming, Laser beam forming-principles and process parameters, Advantages, limitations and applications of different forming processes. Orbital forging-Isothermal, Hot and cold isostatic pressing-High speed extrusion, Water hammer forming, Incremental Sheet forming, Magnetic Pulse forming, Metal Spinning, Electro Hydraulic Forming, Micro forming.

Unit 3	**Weld Metallurgy**

Weld thermal cycles and their effects, effects of pre and post weld heat treatments, concept of HAZ, concept of weldability and its assessment. Welding of dissimilar materials, Weld characterization, Weld decay and weld sensitization, Introduction to ASME, ASWE, IS Welding Standards, (welding skill levels)

Unit 4	**Solid State Welding Processes**

Cold pressure welding, Diffusion bonding, Explosive welding, Ultrasonic welding, Friction stir welding, Forge welding, Roll welding and Hot pressure welding processes - features, advantages, limitations and applications, Advances in adhesive bonding, cladding.

Unit 5	Advanced Welding Processes
Electro gas, electro slag welding, Atomic hydrogen welding, Electron beam welding, Laser Beam welding - principle, working and applications, Cold Metal Transfer - concepts, processes and applications, Underwater welding, Welding automation in aerospace, nuclear and surface transport vehicles, Robotic Welding, Plasma Arc Welding, Plasma Transferred Arc Welding.	
Unit 6	**Sustainable Manufacturing**
Introduction to sustainability and drivers for sustainable development and sustainable manufacturing, fundamentals of sustainable manufacturing, various tools, factors of sustainability, Principles of Life Cycle Assessment (Goal, Scope and Life Cycle Inventory), Approaches, Role in Industry 4.0, Green Manufacturing, Environment protection norms, ISO 14000, recycling techniques, safety norms in forming and welding, socio-economic aspects, case study on waste recycling, material recycling, etc.	

Books and other resources

Text Books:

1. Sindo Kou, “Welding Metallurgy”, Wiley Publications Second Edition
2. Dr. V. D. Kodgire and S. V. Kodgire, “Material Science and Metallurgy For Engineers”, Everest Publication
3. William D. Callister, “Materials Science and Engineering an Introduction”, Jr, John Wiley and Sons, Inc.
4. O.P. Khanna, " Welding Technology", Dhanpat Rai and Sons Publications Edition 2015
5. Dr. R. S. Parmar,"Welding Processes and Technology", Khanna Publications Edition 2017
6. J. Paulo Davim, " Sustainable Manufacturing", Wiley Publications Edition 2010

References Books:

1. Z. Marciniak, J.L.Duncan, "Mechanics of Sheet Metal Forming", Butterworth Heinemann, 2002.
2. Dr. Sadhu Singh, "Theory of Plasticity and Metal Forming Processes", Khanna Publishers Edition 2008
3. O.P. Khanna, " Engineering Metallurgy", Dhanpat Rai and Sons Publications
4. Ali Hasan - Islam Nawaz, "Advanced Welding Technology", SCITECH Publications India Pvt. Ltd. Edition 2018
5. Dr. K. S. Yadav, "Advanced Welding Technology"', Rajsons Publications Pvt. Ltd.
6. Tool and Manufacturing Engineers' Handbook: Forming V by Charles Wick Publisher Society of Manufacturing Engineers; 4th edition (1 Aug. 1996)
7. Dornfeld and David, "Green Manufacturing" - Fundamentals and Applications, DOI 10.1007/978.1.4419.6016.0_2, Springer Science +Business Media, New York 2013
8. R. Ganesh Narayanan, Jay S Gunasekera,"Sustainable Material Forming and Joining”, by CRC Press 2020

Web References:

1. NPTEL Course on “Forming” by Dr. R. Chandramouli, IIT Madras
2. NPTEL Course on “Welding Engineering” by Dr. D. K. Dwivedi, IIT Roorkee
3. NPTEL Course on “Advances in welding and joining technologies” by Prof. SwarupBag IIT Guwahati.
4. NPTEL Course on “Welding Metallurgy” by Prof. Pradeep K. Jha, IIT Roorkee
5. NPTEL Course on “Sustainability through Green Manufacturing System – An Applied Approach” by Prof. Deepu Philip IIT Kanpur and Dr. Amardeep Singh Oberaoi, NIT Jalandar

302525-B: Optimization Techniques					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	3	**In-Semester**	30 Marks
Practical	--	**Practical**	--	**End-Semester**	70 Marks

Prerequisites: Manufacturing Processes, Engineering Mathematics, Machine shop.

Course Objectives:

1. To understand the need and origin of the optimization methods.
2. To understand various linear, nonlinear and other optimization techniques.
3. To understand various multi criterion and multi-objective decision making methods.
4. To understand recent tools in optimization.

Course Outcomes: On completion of the course the learner will be able to;

CO1: Identify the types of optimization problems and apply the calculus method to single variable problems.
CO2: Formulate the problem as Linear Programming problem and analyze the sensitivity of a decision variable.
CO3: Apply various linear and non-linear techniques for problem solving in various domain.
CO4: Apply multi-objective decision making methods for problem in manufacturing environment and other domain.
CO5: Apply multi criterion decision making methods for problem in manufacturing environment and other domain.
CO6: Apply Modern Optimization tools.

Course Contents

Unit 1	**Introduction to Optimization**

Basic Concepts: Statement of the Optimization Problem, Basic Definitions, Optimality Criteria for Unconstrained Optimization, Optimality Criteria for Constrained Optimization, Engineering Application of Optimization, Classification of Optimization Problems. Classical Optimization Techniques: Single variable optimization.

Unit 2	**Linear Programming Problems**

Linear Programming Problem: Formulation, Simplex method, Big M Method, Two Phase, Primal to Dual, Dual Simplex method, Sensitivity Analysis and applications of LP. Transportation and Assignment Models.

Unit 3	**Integer Programming Model**

Integer Programming Model: Gomory's cutting plane method, Branch and Bound Technique. Non L.P. Model: Lagrangian method and Kuhn tucker Method, Newton's method. Discrete Event Simulation: Generation of Random Variable, Simulation Processes, Monte-Carlo Technique.

Unit 4	**Multi Objective Decision Making Methods**

Multi Objective Decision making (MODM) Methods: Introduction to Multi objective optimization, Traditional Techniques such as, quadratic programming, geometric programming, Numerical on goal programming and dynamic programming. Introduction to Non-traditional optimization Techniques such as Genetic Algorithm, particle swarm, genetic algorithms, simulated annealing and Techniques based on Neural network and Fuzziness (Only concepts).

Unit 5	**Multi Criterion Decision Making Methods**

Multi Criterion Decision-making (MCDM) Methods: Introduction to multi criterion optimization Simple Additive Weighting (SAW) Method Weighted Product Method (WPM) Analytic Network Process (ANP) Analytic Hierarchy Process (AHP) Method TOPSIS Method PROMETHEE

Unit 6	**Modern methods of Optimization**

Genetic Algorithms, Simulated Annealing, Ant colony optimization, Tabu search, Neural-Network based Optimization, Fuzzy optimization techniques, Applications of all the techniques. Use of Matlab to solve optimization problems.

Books and other resources

Text Books:

1. S.S. Rao, "Engineering Optimization - Theory and Practice", John Wiley and Sons Inc.
2. Ranjan Ganguli, "Engineering Optimization - A Modern Approach" Universities Press
3. L.C. Jhamb, "Quantitative Techniques Vol. 1 and 2", Everest Pub. House

References Books:

1. Pablo Pedregal, "Introduction to Optimization", Springer
2. Pierre D.A., "Optimization, Theory with Application", John Wiley and sons.
3. R V Rao, “Decision Making in the Manufacturing Environment Using Graph Theory and Fuzzy Multiple Attribute Decision Making” (Springer Publication).
4. Ritter, H., Martinetz, T. Schulten, K., Addison, “Neural Computation and Self-Organizing Maps”-Wesley Publishing Company
5. Douglas C. Montgomery, “Design and analysis of experiments”(John Wiley and Sons Inc.)

Web References:

1. https://www.aicte-india.org/flipbook/pandap/Vol.%20II%20UG/UG_2.html#p=8
2. https://www.britannica.com/topic/operations-research

302526: Robotics Programming Lab					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	02 Hrs/week	**Practical**	1	**Term Work**	25 Marks

Prerequisites: The only prerequisite is an undergraduate controls course. However, this course uses Matlab extensively.

Course Objectives:

1. To introduce different types of robotics and demonstrate them to identify different parts and components.
2. To write programming for simple operations.

Course Outcomes: On completion of the course the learner will be able to;

CO1: Select Use of any robotic simulation software to model the different types of robots and calculate work volume for different robots

CO2: Read and Analyse variety of industrial robots

CO3: Apply Concept of Robot design and program for different field application.

CO4: Evaluate the significance of industrial robot

Guidelines for Laboratory Conduction

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

Total 9 practical Assignments from the following list must be performed. Term work of the student is evaluated based on the completion of practical, Case study and Group Assignment.

1. Demonstration – Robot Anatomy >>> Robot Safety and features, interlocks, etc. >>> Robotic cell design considering safety aspect >>> Do's and Don'ts during Robot operation / programming, etc.
2. Detail study of Robot Configuration – PUMA/SCARA, etc. with detailed specification
3. How to program? – Control Unit / Offline Program >>> Connectivity / interfacing of Robot with Controller
4. Types of Robot Programming – Brief discussions
5. Lead through programming
6. Basic Robot Programming languages, Basic commands for operations, etc.
7. Demonstration of Industrial Robot / Visit
8. To study the Robot programming for industrial applications
9. To study Palletizing application using AL
10. To study Palletizing application using KAREL
11. To study the Robot programming application in VAL II.
12. Palletizing application in VAL II
13. To perform the Robot programming exercise for Pick and Place operation.
14. Case study: Robot application for Spray painting, welding, etc.
15. Presentation by students on some case study – Self study

Books and Other Resources

1) Cameron Hughes Tracey Hughes, Robot Programming: A Guide to Controlling Autonomous Robots, 1/e First Edition, 2016, ISBN: 9789332577442

2) S. R. Deb, Robotics Technology and Flexible Automation, 2010. McGraw Hill ISBN: 9780070077911

3) Mikell. P. Groover, Industrial Robotics: Technology, Programming, and Applications 2nd Edition, McGraw Higher Ed. 2012, ISBN: 9781259006210,
4) Industrial Robotics Technology, Programming and Applications, McGraw Hill Co, 1995.
5) Robotics Lab manual, 2007.

302047: Skill Development					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	02 Hrs/week	**Practical**	1	**Term Work**	25 Marks

Prerequisites: Students should have knowledge of Construction and working of Industrial Robot / Automation System. Working principles of any type of mechanism / power plants. Working of machine tools, engine and transmission of different automotive and home appliances. Advanced manufacturing processes. Solid mechanics and design of machine elements.

Course Objectives:

1. INTRODUCE the skills required in an industry such as design, development, assembly and disassembly.
2. DEVELOP the skills required for fault diagnose of engine and transmission of different automotive and various home appliances.
3. ESTABLISH the skills required for maintenance of any machine tool.
4. CREATE awareness about industrial environment.

Course Outcomes: On completion of the course the learner will be able to;

CO1: APPLYand DEMONSTRATE procedure of assembly and disassembly of various machines.
CO2: DESIGN and DEVELOP a working/model of machine parts or any new product.
CO3: EVALUATE fault with diagnosis on the machines, machine tools and home appliances.
CO4: IDENTIFY and DEMONSTRATE the various activities performed in an industry such as maintenance,
design of components, material selection.

Course Contents

1. Assembly and Disassembly of any of the following mechanical systems/ subsystems: bicycle (geared), e-Bikes, e-Motor Cycles, Drones, Flying devices, gear box, IC engines, centrifugal pump etc.
2. Assembly- Disassembly/ Fault diagnosis of home appliances such as mixer, grinder, washing machine, fan, ovens, gas geyser, chopping machine, kneading machine, exercise machines, etc.
3. Development and demonstration of working/animation model of any mechanism.
4. Design a circuit of electric and hydraulic system of4 wheelers and its verification. OR Circuit design /PCB design using software for control of BLDC electric motors used in e-Vehicles.
5. Undertake total preventive maintenance for any machine tool or mechanical system.
6. Visit to an industry for awareness about preventive maintenance.
7. Use of ergonomic principles for the design of hand tools, control in automobile dashboards, human operated mobile devices.
8. Use of alternative materials in the construction of daily activity machine and tool components
9. Interpretation of Drawings; Exercises in identifying the type of production, extracting important functional dimensions, checking the number of parts in an assembly. Checking and listing missing dimensions.
10. Exercises in -preparation of detailed production drawings as per BIS standard of simple machine parts having relevant notes and indications (limits/tolerances, surface finish, the process of production, relevant tools, materials, measuring instruments). The documentation activity as a part of the Term work shall not be restricted to merely generation of 2D/3D CAD Drawings with dimensions (as applicable), Exploded View, Flowchart of Maintenance Work etc. but can be beyond. Skill Development Documentation Diary must be maintained by every student.

The documentation activity as a part of the Term work shall not be restricted to merely generation

of 2D/3D CAD Drawings with dimensions (as applicable), Exploded View, Flowchart of Maintenance Work etc. but can be beyond.
Skill Development Documentation Diary must be maintained by every student.

302048: Audit Course V		
Teaching Scheme	**Credits**	**Examination Scheme**
--	Non-Credit	--

GUIDELINES FOR CONDUCTION OF AUDIT COURSE

Faculty mentor shall be allotted for individual courses and he/she shall monitor the progress for successful accomplishment of the course. Such monitoring is necessary for ensuring that the concept of self-learning is being pursued by the students 'in true letter and spirit'.

- If any course through Swayam/ NPTEL/ virtual platform is selected the minimum duration shall be of 8 weeks.
- However if any of the course duration is less than the desired (8 weeks) the mentor shall ensure that other activities in form of assignments, quizzes, group discussion etc. (allied with the course) for the balance duration should be undertaken.

In addition to credits courses, it is mandatory that there should be an audit course (non-credit course) from third year of Engineering. The student will be awarded grade as AP on successful completion of the audit course. The student may opt for any one of the audit courses in each semester. Such audit courses can help the student to get awareness of different issues which make an impact on human lives and enhance their skill sets to improve their employability. List of audit courses offered in the semester is provided in the curriculum. Students can choose one of the audit courses from the list of courses mentioned. Evaluation of the audit course will be done at institute level.

The student registered for audit course shall be awarded the grade AP and shall be included such grade in the Semester grade report for that course, provided student has the minimum attendance as prescribed by the Savitribai Phule Pune University and satisfactory in-semester performance and secured a passing grade in that audit course. No grade points are associated with this 'AP' grade and performance in these courses is not considered in the calculation of the performance indices SGPA and CGPA. Evaluation of the audit course will be done at institute level itself.

Selecting an Audit Course

List of Courses to be opted (Any one) under Audit Course V

- Entrepreneurship and IP strategy
- Engineering Economics
- Mangment of Inventory Systems # The titles indicated above are subject to change in time to come and such an alteration (if any) should be brought to the notice of the BOS.

Using NPTEL Platform: (preferable)

NPTEL is an initiative by MHRD to enhance learning effectiveness in the field of technical education by developing curriculum based video courses and web based e-courses. The details of NPTEL courses are available on its official website www.nptel.ac.in

- Students can select any one of the courses mentioned above and has to register for the corresponding online course available on the NPTEL platform as an Audit course.
- Once the course is completed the student can appear for the examination as per the guidelines on

the NPTEL portal. • After clearing the examination successfully; student will be awarded with a certificate.
Assessment of an Audit Course
• The assessment of the course will be done at the institute level. The institute has to maintain the record of the various audit courses opted by the students. The audit course opted by the students could be interdisciplinary. • During the course students will be submitting the online assignments. A copy of the same can be submitted as a part of term work for the corresponding Audit course. • On the satisfactory submission of assignments, the institute can mark as "Present" and the student will be awarded the grade AP on the mark-sheet.

302527: Sensors and Vision Systems in Robots					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	03	**In-Semester**	30 Marks
Practical	02 Hr./Week	**Practical**	01	**End-Semester**	70 Marks
				Practical	50 Marks

Prerequisites: Measurement systems, Sensors, Advanced Robot Sensors, Robot vision.

Temperature, pressure and Flow measurements, Displacement and Velocity measurements, Vision sensors, other sensor like acoustics, vibration, etc., Case Studies, Vision system - Low and Higher level vision, Robot Vision

Course Objectives:

1. UNDERSTAND measurement of different parameters and measurement system behaviour.
2. UNDERSTAND the principle of sensors and its types/characteristics.
3. UNDERSTAND the vision based image classification, object recognition and object detection.
4. UNDERSTAND how to improve image quality using image processing.
5. UNDERSTAND how to extract useful information from image contents through processing.
6. UTILIZE the ROS and open CV Library.

Course Outcomes:

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

CO1. DETERMINE measurement of different parameters and measurement system behaviour.

CO2. DEFINE the principle of sensors and its types/characteristics.

CO3. DEFINE the vision based image classification, object recognition and object detection.

CO4. EVALUATE image quality using image processing.

CO5. DEVELOP useful information from image contents through processing.

CO6. DEFINE ROS and open CV Library.

Course Contents

Unit 1	**Measurement Systems**

Errors: Expected Uncertainty and Probability and Statistics, Instrument Characteristics and Zero Order Systems, Force and Strain Measurements, Temperature Measurements, Pressure Measurements, Flow Measurements, Rotational Frequency Measurements, Power Measurements, Drag Force.

Measurement System Behavior: First Order Systems - Computerized Data Acquisition, Heat Transfer Basics, Dynamic Response of a Thermocouple.

Measurement System Behavior: Second Order Systems - Analysis of a U-Tube Manometer, Lab View.

Unit 2	**Robot Sensors**

Types of sensors; Motion Sensors – Encoder (Absolute and incremental), Lidar, Eddy Current, Proximity (Optical, Inductive, Capacitive), MEMS Accelerometer; Temperature sensor –Pyrometer, Infrared Thermometer, Force / Pressure Sensors – Strain gauges, Piezoelectric sensor, Flow sensors – Electromagnetic, Ultrasonic, Hot-wire anemometer, Acoustic sensor – TSM Resonator, SAW, SHAPM, FPW, Vibration Sensor – Strain Gauge, Microphone or Pressure, Vibration Meter, Vibration Data Logger, Color sensor – RGB type, Vision Sensor - Photoelectric sensors, Smart cameras, Monochrome and color model, Biosensors – Enzyme, ECG, EMG.

Unit 3	**Vision System and Application**

Basic Components: Elements of visual perception: structure of human eye, Image formation in the eye – pinhole cameras - color cameras – Image formation model – Imaging components and illumination techniques - Picture coding – Basic relationship between pixels - Camera-Computer interfaces.

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

Unit 4	**Low-Level Vision**

Image representation: Gray level transformations, Histogram equalization, Image subtraction, Image averaging – Filters: Smoothing spatial filters, sharpening spatial filters, smoothing frequency domain filters, sharpening frequency domain filters - Edge detection.

Unit 5	**Higher-Level Vision**

Segmentation: Edge linking and Boundary Detection, Thresholding, Region-oriented segmentation, the use of motion – Description: Boundary Descriptors, Regional Descriptors, Recognition: Decision-Theoretic methods, structural methods.

Unit 6	**Robot Vision**

Basic introduction to Robotic operating System (ROS): Installing and testing ROS camera Drivers, ROS to Open CV - The CV bridge Package. Introduction to Open CV image processing library and MATLAB programming.

Books and other resources

Text Books:

1. Theory and Design for Mechanical Measurements, 3rd Edition, Figliola and Beasley, Wiley, 2000.
2. K. S. Fu, R. C. Gonzalez, CSG. Lee, Robotics control, sensing, vision and Intelligence, McGraw Hill Education Pvt. Ltd., 2013.
3. Richard D Klafter, Thomas A Chmielewski, Michael Negin, Robotics Engineering: An Integrated Approach, PHI Learning, New Delhi, 2009.

References Books:

1. Damian M Lyons, Cluster Computing for Robotics and Computer Vision, World Scientific, Singapore, 2011.
2. Rafel C. Gonzalez, Richard E. Woods, Steven L. Eddins, Digital Image Processing using MATLAB, 2nd edition, Tata McGraw Hill, 2010.
3. Carsten Steger, Markus Ulrich, Christian Wiedemann, Machine Vision Algorithms and Applications, WILEY-VCH, Weinheim, 2008.
4. Kenneth Dawson-Howe, ―A Practical Introduction to Computer Vision with Open CV, Wiley, Singapore, 2014.

Web References:

Mechanical Measurements, Beckwith, Marangoni, and Lienheard.

Fundamentals of Engineering Thermodynamics, Moran and Shapiro.
Mechanics of Materials, Beer and Johnston.
Fundamentals of Fluid Mechanics, Munson, Young, and Okiishi.
Heat Transfer", Incopera and Dewitt.
Applied Statistics and Probability for Engineers, Montgomery and Runger.
Fundamentals of Fluid Mechanics, Munson, Young, and Okiishi.

Web Links:

www.omega.com/techref/
www.tmworld.com/
www.measurementsgroup.com/
http://www.convert-me.com/en/

Guidelines for Laboratory Conduction

The student shall perform any 7 experiments of the following:

1. Data acquisition of physical phenomenon / Interfacing of sensors for monitoring the physical quantities (distance, pressure, temperature, light intensity) and raising an alarm/ actuating a signal if the quantity exceeds specified limit.

2. Interfacing data acquisition system hardware with computer to measure and control the robotic system.

3. Integration of assorted sensors (IR, Potentiometer, Strain Gauges etc.,) Micro controllers and ROS in a robotic system.

4. Color Image Segmentation algorithm development.

5. Image processing using open CV.

6. Image processing and recognition for color and shape detection (recognizing simple objects based on features).

7. One industrial visit for industrial robotic application.

8. Case study on i. Computer Vision for the Operation of Unmanned Aerial Vehicles. ii. Identifying different objects and classifying them. iii. Action understanding in human. iv. Augmented Human Assistance. v. Gesture Interpretation for the Analysis of Interactions Humans/Robots/Humans. vi. Context Aware Vision using Image-based Active Recognition.

Guidelines for Practical Sessions:

1. Assessment must be based on understanding of theory, attentiveness during practical, and understanding.

2. There should be continuous assessment and Timely submission of journal.

Term Work

The student shall complete the following activity as a Term Work:

Six assignments based on unit 1 to unit 6.

302528: Artificial Intelligence in Robots					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	03	**In-Semester**	30 Marks
Practical	02 Hr./Week	**Practical**	01	**End-Semester**	70 Marks
				Practical	50 Marks

Prerequisites: Engineering Mathematics, Python**.**

Course Objectives:

1. Study the concepts of Artificial Intelligence and Machine learning.
2. Learn the methods of solving problems using Artificial Intelligence.
3. Learn about knowledge, planning and reasoning artificial intelligence.
4. Application of AI and ML in Robotics

Course Outcomes:

CO1: To UNDERSTAND the basics of Artificial Intelligence, Intelligent Agents and its structure
CO2: To UNDERSTAND the basic forms of Machine Learning, decision trees and statistical Learning setting
CO3: To UNDERSTAND the problem solving by various searching techniques
CO4: To UNDERSTAND the application of Supervised Learning
CO5: To APPLY the knowledge of AI and ML in Robotics
CO6: To APPLY the knowledge of AI and ML for real time applications.

Course Contents

Unit 1	**Introduction to AI and ML**

Introduction to Artificial Intelligence: Define AI, History of AI, Need of AI in Robotics, Problems of AI, AI: Application areas, The state of the art, Future of AI. Thinking and acting humanly, intelligent agents, structure of agents
Introduction to Machine Learning: Define ML, Types of Learning, History of Machine Learning. AI Vs ML
Basics: Problem solving, Knowledge representation and Reasoning,
Approaches to AI: Cybernetics and brain simulation, Symbolic, Sub-symbolic, Statistical.

Unit 2	**Introduction to Data Structures and Algorithm Analysis**

Introduction, Need of Data Structure, Definitions - Data and information, Data type, Data object, ADT, Data Structure, Types of Data Structures, Algorithm analysis, Space and time complexity, Graphical understanding of the relation between different functions of n, examples of linear loop, logarithmic, quadratic loop etc., Best, Worst, Average case analysis, Asymptotic notations (Big O, Omega Ω, Theta θ), Problems on time complexity calculation.

Unit 3	**Feature Extraction and Selection**

Feature extraction: Statistical features, Principal Component Analysis.
Feature selection: Ranking, Decision tree - Entropy reduction and information gain, Exhaustive, best first, Greedy forward and backward, Applications of feature extraction and selection algorithms in Mechanical Engineering.

Unit 4	Supervised and Unsupervised Learning

Supervised Learning: Linear Regression, Logistic Regression, Support Vector Machine, Decision tree, random forest, boosting algorithms, K-Nearest Neighbor (KNN).

Unsupervised Learning: K-Means Clustering, Anomaly detection, Applications of Unsupervised.

Advanced supervised learning

Unit 5	Reinforced and Deep Learning in Robotics

Characteristics of reinforced learning; Algorithms: Value Based, Policy Based, Model Based; Positive vs Negative Reinforced Learning; Models: Markov Decision Process, Q Learning, Characteristics of Deep Learning, Artificial Neural Network, Convolution Neural Network, Application of Reinforced and Deep Learning in Mechanical Engineering.

Unit 6	ML Model Development and Applications in Robotics

Model training and validation, Hyperparameter tunning, Model evaluation, Predictions.
Human Machine Interaction, Fault Detection, Image based part classification, Process Optimization, Material Inspection.
Case studies: Case studies on supervised learning, unsupervised, Human-robot collaboration.

Books and other resources

Text Books:

1. Artificial Intelligence A Modern Approach Third Edition by Stuart J. Russell and Peter Norvig David Jefferis.
2. Introduction to Machine Learning Third Edition by Ethem Alpaydın
3. Peter Flach, Machine Learning: The Art and Science of Algorithms that make sense of data_, Cambridge, 2014.
4. Negnevitsky, M, Artificial Intelligence: A guide to Intelligent Systems‖,. Harlow: Addison-Wesley, 2011.

References Books:

1. Artificial Intelligence A Modern Approach Third Edition by Stuart J. Russell and Peter Norvig David Jefferis.
2. Introduction to Machine Learning Third Edition by Ethem Alpaydın
3. Artificial Intelligence: Robotics and Machine Evolution‖, Crabtree Publishing Company, 1999.
4. Mohri, Rostamizdeh, Talwalkar, Foundations of Machine Learning, MIT Press, 2018.

Web References:

1. http://nptel.ac.in/courses/111101003/
2. https://nptel.ac.in/courses/106/106/106106202/
3. https://nptel.ac.in/courses/112/103/112103280/
4. https://www.analyticsvidhya.com/

Practical Work

The student shall complete the following activity as a Practical Work:

1. To study supervised/unsupervised/Reinforcement learning approach.
2. To acquire, visualize and analyze the data set (from time-domain/ frequency-domain/ etc.) .
3. To extract features from given data set and establish training data.
4. To select relevant features using suitable technique.

OR

5. To use PCA for dimensionality reduction.
6. To classify features/To develop classification model and evaluate its performance (any one classifier).

7. To develop regression model and evaluate its performance (any one algorithm).
8. Markov process for modeling manufacturing processes.

OR

9. Reinforced Learning for optimizing engineering designs / Robot Guidance and Navigation.
10. GA for optimization of multi-dimensional function / path planning in robotics.

OR

11. NN for parameter and model identification / tuning of Control Algorithms.

Note:

- Students need to apply the computational algorithms using suitable software / programming language.
- Experiment 1, 2, 3, 6 and 7 are compulsory. Experiment 2 to 7 to be taken on same data set.

302529 : Modeling and Simulation

Teaching Scheme		Credits		Examination Scheme	
Theory	03 Hr./Week	**Theory**	03	**In-Semester**	30 Marks
Practical	02 Hr./Week	**Practical**	01	**End-Semester**	70 Marks
				Practical	50 Marks

Prerequisites: Machine Drawing, Engineering Mathematics, MATLab and Simulink

Course Objectives:

1. To provide an overview of how computers are being used in system simulation with the use of various Handle software packages.
2. To provide an overview of application of simulation to manufacturing systems.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Solve the problems based on simulation principal
CO2: Differentiate the simulation systems.
CO3: Collect data and generate the random numbers.
CO4: Distinguish simulations with regard to output analysis
CO5: Apply simulation to manufacturing system.
CO6: Handle software packages – ARENA/SimFactory/Promodel/ Witness

Course Contents

Unit 1	**Principles of Simulation and Modeling**

A review of basic probability and statistics, Definition and concepts of simulation and modeling, steps in a simulation study, Modeling concepts, Advantages, Disadvantages and Applications areas of simulation Basic principles of simulation modeling, Model based problem solving.

Unit 2	**System Simulation**

Types of simulation: Physical vs. Mathematical, Static vs. Dynamic, Deterministic vs. Stochastic, Continuous vs. Discrete simulation models, Continuous, Discrete event, Monte-Carlo simulation methods and their applications in inventory and queuing problems (single server queuing system) – problem organization and logic.

Unit3	**Input Data Analysis**

Nature of simulation, Roots of simulation input modeling, Data collection, Identifying distribution, Histograms, practical methods for testing assumptions Random Number Generation: Introduction, Desired properties, Generation of pseudo random numbers.

Unit 4	**Random Variate Generation**

Introduction, Factors considered in selecting generator, Generating continuous random variates like Uniform, Exponential, Weibull, Normal Output Data Analysis: Introduction, Types of simulations with regard to output analysis – terminating and non terminating simulation.

Unit 5	Simulation of Manufacturing Systems
Need of simulation in manufacturing and material handling systems, Components of manufacturing systems – product, resources, demand, control; Downtime, Rework and reentrancy, Random events and performance measures used in manufacturing systems with a case study on any manufacturing system Material Handling Systems – Input parameters for automated material handling systems, Conveyor and vehicle systems, job shop with material handling and flexible manufacturing systems.	
Unit 6	**Simulation Software**
Simulation software: Introduction, Comparison of simulation software with programming languages – SLAM, SIMAN. Desirable software features, Classification of simulation software, General purpose and object oriented simulation software packages – ARENA/SimFactory/Promodel/ Witness.	
Books and other resources	
Text Books: 1. Averill M Law, "Simulation Modeling and Analysis", Fourth Edition, Tata McGraw Hill Education Private Ltd, New Delhi, 2010.	
References Books: 4. Banks, J., J. S. Carson II, and B. L. Nelson. "Discrete-Event System Simulation", Second Edition, Prentice Hall, Upper Saddle River, New Jersey, 1996 5. Fishman, G.S., "Monte Carlo: Concepts, Algorithms and Applications", Chapman and Hall, New York, 2006.	
Web References: https://nptel.ac.in/courses/112107220	
The student shall complete the following activity as a Practical Work: 1. Introductions to programming with MATLAB. 2. Case study on use of Simulink in MATLAB for engineering problems. 3. Case study on use of Neural Network in MATLAB for engineering problems. 4. Use of MATLAB for engineering problems. 5. Case study on Simulation of Engineering system 6. Case study on Input data analysis 7. Case study on simulation of manufacturing system	

Savitribai Phule Pune University
Board of Studies - Mechanical and Automobile Engineering
Undergraduate Program - Automation and Robotics (2019 pattern)

302530-A: Machining Science and Technology					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	03	**In-Semester**	30 Marks
Tutorial	--	**Tutorial**	--	**End-Semester**	70 Marks
				Practical	--

Prerequisites:
Data science syllabus includes a comprehensive curriculum, which is designed on the basis of what most industries want from data science professionals. The data science syllabus is suitable for students who want to pursue career in data science.

Course Objectives:
1. To provide an overview of nontraditional machining techniques.
2. To Illustrate mechanism of material removal describe the process parameters, advantages and limitations, applications and model for material removal rate for industrially relevant NTM techniques.

Course Outcomes:
On completion of the course the learner will be able to:
CO1: ANALYZE cutting forces in turning and learn problem solving skills in both analytical and graphical methods.
CO2: CATEGORIZE cutting force measuring instruments and choose them for a particular application.
CO3: UNDERSTAND Outline tool wear, tool geometry, tool temperature and parameters influencing tool life.
CO4: ANALYSE cutting forces.
CO5: UNDERSTAND concept of Estimates of machining costs.
CO6: UNDERSTAND Modern machining techniques.

Course Contents

Unit 1	**Mechanics of Metal Cutting**

Mechanism of chip formation, Orthogonal and Oblique cutting, types of chips, built-up edge, Determination of shear plane angle, forces on the chips, forces in orthogonal cutting, Merchant circle diagram and analysis, theory of Ernst and Merchant, comments on shear plane angle, theory of Lee and Shaffer, friction in metal cutting, power and energy relationship, specific cutting energy, velocity relationship, shear-strain, factors affecting forces and power, Problems.

Unit 2	**Geometry of Cutting Tools**

Single point and multi point cutting tools, tool angle specifications– ISO and ASA systems, effect of cutting parameters on tool geometry. Characteristics of tool materials, types of tool materials, recommended cutting speeds for the above tools and tool inserts

Unit3	**Tool Wear, Tool Life**

Mechanisms of tool wear, Sudden and gradual wear, crater wear, flank wear, tool failure criteria-direct and indirect, tool life equations, tool life tests-conventional and accelerated, effect of process

parameters on tool life, tool wear measurement, machinability index, Problems.	
Unit 4	**Measurement of Cutting Forces**
Reasons for measuring cutting forces, dynamometer requirements, Classification of cutting force dynamometers – mechanical, hydraulic, pneumatic, optical, inductance, piezoelectric, and strain gage type dynamometers, Dynamometers for lathe, drilling and milling.	
Unit 5	**Economics of Machining**
Introduction, elements of total production cost, optimum cutting speed and tool life for minimum cost, optimum cutting speed and tool life for maximum production, Problems.	
Unit 6	**Modern Machining Techniques**
Introduction to modern machining- History, need, classification Process description, mechanism of metal removal, effect of parameters, and modeling of i) Ultrasonic Machining (USM), ii) Abrasive Water Jet Machining (AWJM), iii) Electrical Discharge Machining (EDM) and iv) Laser Beam Machining (LBM) Modeling – Empirical and Analytical models.	
Books and other resources	
Text Books: 1. Fundamentals of metal cutting and Machine Tools - by B. L. Juneja and G.S – Sekhar - Wiley Eastern. 2. Advanced machining process - Vijay K. Jain, Allied Publishers PVT. Limited	
References Books: 1. Metal Cutting Principles - M.C. Shaw - Oxford Publication 2. Metal Cutting - Dr. B. J. Ranganath -Vikas Publications. 3. Fundamentals of machining and machine tools - Boothroyd and Knight – Taylor and Francis 4. Production Technology - HMT - Tata Mc Graw Hill 5. Modern Machining Process - P.C Pandy and H.S. Shan - Tata McGraw Hill	
Web References: 1. http://nptel.ac.in/downloads/112105127/ 2. http://fmcet.in/MECH/ME6402_uw.pdf 3. http://www.gitam.edu/eresource/images/Mechanics_of_Metal_Cutting.pdf 4. http://nptel.ac.in/courses/112105126/36	

Savitribai Phule Pune University
Board of Studies - Mechanical and Automobile Engineering
Undergraduate Program - Automation and Robotics (2019 pattern)

302530-B : Maintenance and Safety Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	03 Hr./Week	**Theory**	3	**In-Semester**	30
Practical	--	**Tutorial**	--	**End-Semester**	70
				Term-Work	--

Prerequisites: Basic Mechanical Engineering, Manufacturing Process, Engineering Mathematics.

Course Objectives:

1. To acquainted with industrial maintenance processes and breakdowns.
2. To learn the safety aspects, planning and operation of plants in industry.

Course Outcomes:

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

CO1: SELECT the relevant safety plan and procedure for industry.
CO2: USE the different hazard assessment technique in Chemical industry.
CO3: PREPARE accident investigation reports in Chemical Industry.
CO4: USE hazard control methods for industrial hazards.
CO5: USE the relevant maintenance procedure in Chemical process plant.
CO6: UNDERSTAND safety aspects in industrial operations.

Course Contents

Unit 1	**Quality, Reliability and Maintainability(QRM)**

Productivity; Quality and Quality circle in Maintenance, engineering Reliability, Reliability Assurance through Redundancy, Maintainability and maintainability improvement, Maintainability vis a vis Reliability.

Unit 2	**Maintenance jobs and Technologies**

Wear and service life of equipment: Methods of assembly and fitting – assembly of keyed joints, splined joints, fixed joints, assembly of ball and roller bearings, repairs and assembly of gears. Wear of machines- types and reasons to wear, defects due to wear of equipment, corrosion, and its prevention. Recovery and strengthening of machine elements various methods of recovery and increasing service life.

Unit 3	**Maintenance Types/Systems**

Planned and unplanned Maintenance, Breakdown Maintenance, corrective Maintenance, Opportunistic Maintenance, Routine Maintenance, Preventive Maintenance, Predictive Maintenance, Condition Base Maintenance System (CBMS): Online offline Monitoring, Visual and Temperature Monitoring, Leakage Monitoring, Vibration Monitoring: causes, identification, and monitoring. Ferrography, Spectroscopy, Cracks Monitoring. Design Out maintenance, Selection of Maintenance Systems.

Unit 4	Maintenance Planning and Scheduling
Factors involved in effective planning of maintenance work, Various methods of scheduling work, Categorization of plant/equipment for the purpose of priorities. Short term and Long Term Maintenance Plans: Major repair, Capital Repair, and Annual Overhauls, Renovation, Revamping, and Modernization.	
Unit 5	**Safety Engineering**
Introduction, Hazard and Operability Study (HAZOP), Fundamental of Industrial Safety, Types and Categorization of Accidents. Accidents preventions, Safety Training. Onsite offsite Emergency Plans, Job Safety Analysis (JSA), Safety Survey, Reporting of accidents, and dangerous occurrence.	
Unit 6	**Safe Design and Operation of Plants**
Procedure for Ensuring Safety in Planning, Building, and Operating Plants: Process Design, Planning, Construction and Commissioning of Plants, Alarm and Hazard Defense Plans, Information of the Public. Safety measures: Inherent Safety Measures, Passive Safety Measures, Active Safety Measures, Organizational Measures, Design of Safety Systems. Plant Layout and Spacing. Personal Safety and Personal Protective Equipment	
Books and other resources	
Text Books: 1. Industrial Safety Management Deshmukh, L. M. McGraw Hill Education; New York, 2005, ISBN-13: 978- 0070617681 2. Industrial Safety and Health Management Asfahl, C. Ray Rieske, David W. Prentice Hall, N. J. USA, 2009, ISBN-13: 978-007132368711	
References Books: 1. Hazard analysis Techniques for system safety Ericson, Clifton A. Wiley Publication, N.J. USA, 2005, ISBN : 97811 18940389 2. Safe and Efficient Plant Operation and Maintenance (Chemical Engineering. Kraus, Milton N. McGraw-Hill Inc.,New York US, 1980, ISBN: 978-0070107076 3. Chemical Process Safety Crowl, Daniel A., Louvar, Joseph F. Prentice hall, NJ, USA. 2002, ISBN 0-13-018176-5	
Web References: https://onlinecourses.nptel.ac.in/noc20_mg43/preview	

302531 : Metrology and Quality Control in Automation					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	--	**Theory**	--	**In-Semester**	--
Practical	02 Hr./Week	**Practical**	01	**End-Semester**	--
				Term-Work	25 Marks

Term Work

The student shall complete the following activity as a term work journal:

Part: A] Metrology (Any 6)

1. Demonstration of linear and angular measuring instruments using Vernier Caliper, Screw gauge, Dial gauge, height gauge, Bevel protector.
2. Error determination of linear / angular measuring instruments and determination of linear and angular dimensions of given part, (MSA: Gauge R and R).
3. Calibration of following instruments
    a. Vernier caliper, Micrometer (Any one)
    b. Pressure Gauge, Calibration of Thermocouple, Calibration of LVDT, Calibration of Load cell (Any one)
4. Determination of modulus of elasticity of a mild steel specimen using strain gauges/load cell.
5. Measurement of Screw threads Parameters using two wire or Three-wire methods.
6. Measurements of Surface roughness, Using Tally Surf/Mechanical Comparator
7. Measurement of gear tooth profile using gear tooth Vernier /Gear tooth micrometer
8. Object geometry measurements using Optical Projector / Toolmaker Microscope.
9. Measurement of angle using Sine Center / Sine bar / bevel protractor
10. Measurement of Machine tool alignment using Autocollimator / Roller set.
11. Determination of given geometry using coordinate measuring machine (CMM).

Part: B] Statistical Quality Control

12. Analyze the fault in given batch of specimens by using seven quality control tools for engineering application. Submission of these assignments USING STANDAED FORMATS.
13. Determination of process capability from given components and plot variable control chart/ attribute chart.

Part: C] Visit and Case Study

14. Case study on estimation and improvement in process capability.
15. Visit to Calibration lab /Quality control lab / CMM Lab of any Automotive / Engineering Industry.

302532 : Computer Aided Digital Manufacturing Laboratory					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	--	Theory	--	**In-Semester**	--
Practical	02 Hr./Week	Practical	1	**End-Semester**	--
				Term-Work	25 Marks

Course Objectives:

1. ACQUIRE skills to handle conventional machines and CNC machine for manufacturing of a component.
2. PREPARE manual part program for given component as per ISO standards.
3. ACCUSTOM skills of Additive manufacturing technology.
4. APPRECIATE the influence of cutting tool parameters on the performance.
5. APPLY Digital Manufacturing tools for process simulation of manufacturing processes.
6. SELECT appropriate type of jigs and fixtures for a given component

Course Outcomes:

On completion of the course, learner will be able to:
CO1. DEVELOP a component using conventional machines, CNC machines and Additive Manufacturing Techniques.
CO2. ANALYZE cutting tool parameters for machining given job.
CO3. DEMONSTRATE simulation of manufacturing process using Digital Manufacturing Tools.
CO4. SELECT and DESIGN jigs and Fixtures for a given component.
CO5. DEMONESTRATE different parameters for CNC retrofitting and reconditioning.

Term Work

The learner shall complete the following activity as a Term Work;

1. Demonstration and detailed study of cutting tool geometry and nomenclature of the tools used in conventional and CNC machines in automations.
2. Machining of a mechanical component using conventional machines such as lathe, drilling, milling, grinding and any additional machine tool or processes as per requirement. Manufacturing drawing with appropriate geometrical and dimensional tolerances, detailed process planning to be included.
3. Preparing manual CNC part program using G Codes and M Codes as per ISO (DIN 66025) and RS274 standards for CNC lathe/mill machine and advanced machines.
4. Machining of mechanical component using CNC machine (Lathe/Mill/HMC/VMC). Manufacturing drawing with appropriate geometrical and dimensional tolerances, detailed process planning to be included.
5. Demonstration of Additive Manufacturing technology-3D printing (from modelling to printing)

(To be performed Batch-wise)

6. Demonstration of the usage of Digital Manufacturing tools for process simulation of manufacturing processes like casting, forging, sheet metal, plastic processing (free / open source software)
7. Demonstration of various types of jigs and fixtures, and a case study on design and use of Jigs and Fixture for any given component for robot applications.
8. Preparing Online Calculator/Catalogue for selection of cutting parameters by using programming languages like C, Python, MATlab etc.
9. Study on CNC retrofitting and reconditioning.
10. Visit to an Industry which uses advanced automation and robotics technology.

Please note following instructions regarding Laboratory Conduction:

1. Sr. No. 1 to 6 are mandatory and any 2 from Sr. No. 7 to 10.
2. Practical are to be performed under the guidance of concerned faculty member.
3. Journal should consist of Job Drawing, Process Sheet and Program, appropriate write-up and shall be part of term-work submission.

302055: Internship					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	--	Theory	--	In-Semester	--
Tutorial	04Hr./Week	Practical	04	End-Semester	--
				Term-Work	100 Marks

Prerequisites: Knowledge of design, manufacturing processes, modeling, and mechanical systems.

Course Objectives:

Internship provides an excellent opportunity to learner to see understand the conceptual aspects learned in classes and deployed into the practical world. Industry/on project experience provides much more professional experience as value addition to classroom teaching.

1. To encourage and provide opportunities for students to get professional/personal experience through internships.
2. To learn and understand real life/industrial situations.
3. To get familiar with various tools and technologies used in industries and their applications.
4. To nurture professional and societal ethics.
5. To create awareness of social, economic and administrative considerations in the working environment of industry organizations

Course Outcomes:

On completion of the course the learner will be able to;

CO1. DEMONSTRATE professional competence through industry internship.

CO2. APPLY knowledge gained through internships to complete academic activities in a professional manner.

CO3. CHOOSE appropriate technology and tools to solve given problem.

CO4. DEMONSTRATE abilities of a responsible professional and use ethical practices in day to day life. CO5. DEVELOP network and social circle, and DEVELOPING relationships with industry people.

CO6. ANALYZE various career opportunities and DECIDE career goals.

Guidelines

Internships are educational and career development opportunities, providing practical experience in a field or discipline. Internships are far more important as the employers are looking for employees who are properly skilled and having awareness about industry environment, practices and culture. Internship is structured, short-term, supervised training often focused around particular tasks or projects with defined time scales.

Core objective is to expose technical students to the industrial environment, which cannot be simulated/experienced in the classroom and hence creating competent professionals in the industry and to understand the social, economic and administrative considerations that influence the working environment of industrial organizations.

Engineering internships are intended to provide students with an opportunity to apply conceptual knowledge from academics to the realities of the field work/training. The following guidelines are proposed to give academic credit for the internship undergone as a part of the Third Year Engineering curriculum

Duration:

Internship is to be completed after semester 5 and before commencement of semester 6 of at least 4 to 6 weeks; and it is to be assessed and evaluated in semester 6.

Internship work Identification:

Student may choose to undergo Internship at Industry/Govt. Organizations/NGO/MSME/Rural Internship/ Innovation/IPR/Entrepreneurship. Student may choose either to work on innovation or entrepreneurial activities resulting in start-up or undergo internship with industry/NGO's/Government organizations/Micro/Small/ Medium enterprises to make themselves ready for the industry. Students must get Internship proposals sanctioned from college authority well in advance. Internship work identification process should be initiated in the Vth semester in coordination with training and placement cell/ industry institute cell/ internship cell. This will help students to start their internship work on time. Also, it will allow students to work in vacation period after their Vth semester examination and before academic schedule of semester VI. Student can take internship work in the form of the following but not limited to:

1. Working for consultancy/ research project.
2. Contribution in Incubation/ Innovation/ Entrepreneurship Cell/ Institutional Innovation Council/ startups cells of institute.
3. Learning at Departmental Lab/Tinkering Lab/ Institutional workshop.
4. Development of new product/ Business Plan/ registration of start-up.
5. Industry / Government Organization Internship.
6. Internship through Internshala.
7. In-house product development, intercollegiate, inter department research internship under research lab/group, micro/small/medium enterprise/online internship.
8. Research internship under professors, IISC, IIT's, Research organizations.
9. NGOs or Social Internships, rural internship, 10. Participate in open source development.

Internship Diary/ Internship Workbook:

Students must maintain Internship Diary/ Internship Workbook. The main purpose of maintaining diary/workbook is to cultivate the habit of documenting. The students should record in the daily training diary the day-to-day account of the observations, impressions, information gathered and suggestions given, if any. The training diary/workbook should be signed every day by the supervisor. Internship Diary/workbook and Internship Report should be submitted by the students along with attendance record and an evaluation sheet duly signed and stamped by the industry to the Institute immediately after the completion of the training.

Internship Work Evaluation:

Every student is required to prepare and maintain documentary proofs of the activities done by him as internship diary or as workbook. The evaluation of these activities will be done by Program Head/Cell In-charge/ Project Head/ faculty mentor or Industry Supervisor based on- Overall compilation of internship activities, sub-activities, the level of achievement expected, evidence needed to assign the points and the duration for certain activities. Assessment and Evaluation is to be done in consultation with internship supervisor (Internal and External – a supervisor from place of internship. Recommended evaluation parameters-

Post Internship Internal Evaluation -50 Marks + Internship Diary/Workbook and Internship Report - 50 Marks.

Evaluation through Seminar Presentation/Viva-Voce at the Institute

The student will give a seminar based on his training report, before an expert committee

constituted by the concerned department as per norms of the institute. The evaluation will be based on the following criteria:

- Depth of knowledge and skills
- Communication and Presentation Skills
- Team Work and Creativity
- Planning and Organizational skills
- Adaptability
- Analytical Skills
- Attitude and Behavior at work
- Societal Understanding
- Ethics
- Regularity and punctuality
- Attendance record
- Diary/Workbook
- Student's Feedback from External Internship Supervisor

After completion of Internship, the student should prepare a comprehensive report to indicate what he has observed and learnt in the training period. Internship Diary/workbook may be evaluated on the basis of the following criteria:

● Proper and timely documented entries
● Adequacy and quality of information recorded
● Data recorded
● Thought process and recording techniques used
● Organization of the information

The report shall be presented covering following recommended fields but limited to,

- Title/Cover Page
- Internship completion certificate
- Internship Place Details- Company background-organization and activities/Scope and object of the study / Supervisor details
- Index/Table of Contents
- Introduction
- Title/Problem statement/objectives
- Motivation/Scope and rationale of the study
- Methodological details
- Results / Analysis /inferences and conclusion
- Suggestions / Recommendations for improvement to industry, if any
- Attendance Record
- Acknowledgement
- List of reference (Library books, magazines and other sources)

Feedback from internship supervisor(External and Internal)

Post internship, faculty coordinator should collect feedback about student with recommended parameters include as- Technical knowledge, Discipline, Punctuality, Commitment, Willingness to do the work, Communication skill, individual work, Team work, Leadership…

Reference:

1. https://www.aicte-india.org/sites/default/files/AICTE%20Internship%20Policy.pdf
2. https://internship.aicte-india.org/

Mini-project					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	--	**Theory**	--	**In-Semester**	--
Tutorial	04Hr./Week	**Practical**	04	**End-Semester**	--
				Term-Work	100 Marks

Course Objectives:

Students shall UNDERTAKE and EXECUTE a Mini Project through a group of students to :

1. UNDERSTAND the "Product Development Cycle", through Mini Project.
2. PLAN for various activities of the project and distribute the work amongst team members.
3. LEARN budget planning for the project.
4. INCULCATE mechanical/interdisciplinary implementation skills.
5. DEVELOP students' abilities to transmit technical information clearly and test the same by delivery of Seminar based on the Mini Project.
6. UNDERSTAND the importance of document design by compiling Technical Report on the Mini Project work carried out

Course Objectives:

On completion of the course, learner will be able to

CO1. EXPLAIN plan and execute a Mini Project with team.

CO2.IMPLEMENT hardware/software/analytical/numerical techniques, etc.

CO3. DEVELOP a technical report based on the Mini project.

CO4. DELIVER technical seminar based on the Mini Project work carried out

Course Contents

Maximum Group Size: Minimum 2 and maximum 4 students can form a group for the mini project.

Project Type: (The selected mini project must be based on any of the following)

1. Development of a prototype robot.
2. Investigate performance of robotic systems using experimental method
3. Parametric analysis of components/systems/devices using suitable software
4. Investigation of optimum process/material for product development using market survey.
5. Solution for society/industry problems

The Assessment Scheme will be:

a. Continuous Assessment 50 marks (based on regular interaction, circuit development)

b. End Semester 50 marks (based on poster presentation, demonstration / Seminar)

Project domain may be from the following, but not limited to:

1.Thermal Systems

2. Robotics Mechanisms/design systems

3. Production/advance manufacturing

4. Materials: Composite/Nano

5. Automation and Control Systems

6. Mechatronic Systems

7. Agriculture system.

8. Smart systems using AI-ML

A project report with following contents shall be prepared:

1. Title
2. Objectives
3. Relevance and significance

4. Methodology
5. Analysis-Simulation/experimentation/survey/testing etc.
6. Result and Discussion
7. Conclusion

302056 : Audit Course-VI					
Theory	--	**Theory**	--	**In-Semester**	--
Tutorial	--	**Practical**	--	**End-Semester**	--
				Term-Work	--

GUIDELINES FOR CONDUCTION OF AUDIT COURSE

Faculty mentor shall be allotted for individual courses and he/she shall monitor the progress for successful accomplishment of the course. Such monitoring is necessary for ensuring that the concept of self-learning is being pursued by the students 'in true letter and spirit'.

- If any course through Swayam/ NPTEL/ virtual platform is selected the minimum duration shall be of 8 weeks.
- However if any of the course duration is less than the desired (8 weeks) the mentor shall ensure that other activities in form of assignments, quizzes, group discussion etc. (allied with the course) for the balance duration should be undertaken.

In addition to credits courses, it is mandatory that there should be an audit course (non-credit course) from third year of Engineering. The student will be awarded grade as AP on successful completion of the audit course. The student may opt for any one of the audit courses in each semester. Such audit courses can help the student to get awareness of different issues which make an impact on human lives and enhance their skill sets to improve their employability. List of audit courses offered in the semester is provided in the curriculum. Students can choose one of the audit courses from the list of courses mentioned. Evaluation of the audit course will be done at institute level.

The student registered for audit course shall be awarded the grade AP and shall be included such grade in the Semester grade report for that course, provided student has the minimum attendance as prescribed by the Savitribai Phule Pune University and satisfactory in-semester performance and secured a passing grade in that audit course. No grade points are associated with this 'AP' grade and performance in these courses is not considered in the calculation of the performance indices SGPA and CGPA. Evaluation of the audit course will be done at institute level itself.

Selecting an Audit Course

List of Courses to be opted (Any one) under Audit Course VI

- Business and Sustainable Development
- Management Information System
- International Business

The titles indicated above are subject to change in time to come and such an alteration (if any) should be brought to the notice of the BOS.

Using NPTEL Platform: (preferable)

NPTEL is an initiative by MHRD to enhance learning effectiveness in the field of technical education by developing curriculum based video courses and web based e-courses. The details of NPTEL courses are available on its official website www.nptel.ac.in

- Students can select any one of the courses mentioned above and has to register for the corresponding online course available on the NPTEL platform as an Audit course.

- Once the course is completed the student can appear for the examination as per the guidelines on the NPTEL portal.
- After clearing the examination successfully; student will be awarded with a certificate.

Assessment of an Audit Course

- The assessment of the course will be done at the institute level. The institute has to maintain the record of the various audit courses opted by the students. The audit course opted by the students could be interdisciplinary.
- During the course students will be submitting the online assignments. A copy of the same can be submitted as a part of term work for the corresponding Audit course.
- On the satisfactory submission of assignments, the institute can mark as "Present" and the student will be awarded the grade AP on the mark-sheet.