Savitribai Phule Pune University

Faculty of Science & Technology

Curriculum for

Third Year

Robotics and Automation Engineering

(2019 Course)

(with effect from June 2021)

Savitribai Phule Pune University, Pune
TE (Robotics and Automation)
2019 Course
(With effect from Academic Year 2020-21)

Semester-V

Course Code	Course Name	Teaching Scheme (Hours/Week)			Examination Scheme and Marks						Credit			
		Theory	Practical	Seminar	IN-Sem	End-Sem	TW	PR	OR	Total	TH	PR	Seminar	Total
311501(A)	Embedded systems in Robotics	3			30	70				100	3			3
311502(A)	Hydraulics and Pneumatics	3			30	70				100	3			3
311503(A)	Robot Kinematics and Dynamics	3			30	70				100	3			3
311504(A)	Sensors Technology	3			30	70				100	3			3
311505(A)	Elective-1	3			30	70				100	3			3
311501(B)	Embedded systems in Robotics Lab		2				25			25		1		1
311502(B)	Hydraulics and Pneumatics Lab		2					25		25		1		1
311503(B)	Robot Kinematics and Dynamics Lab		2				25	25		50		1		1
311504(B)	Sensors Technology LAB		2						25	25		1		1
311505(B)	Elective-1 lab		2						25	25		1		1
311506	Seminar			1			50			50			1	1
311507	Mandatory Audit Course 5	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	**15**	**10**	**1**	**150**	**350**	**100**	**50**	**50**	**700**	**15**	**5**	**1**	**21**

Elective 1:

I: Statistics and Numerical Methods
II: Finite Element Analysis
III: Industrial Robotics and material handling systems
IV: Intelligent Manufacturing Systems

Mandatory Audit Course 5: Students should select one of the following subjects as an Audit Course

I. Disaster Management
II. Industrial Waste Management

Savitribai Phule Pune University, Pune TE (Robotics and Automation) 2019 Course (With effect from Academic Year 2020-21)														
Semester-VI														
Course Code	**Course Name**	**Teaching Scheme (Hours/Week)**			**Examination Scheme and Marks**						**Credit**			
		Theory	**Practical**	**Internship**	**IN-Sem**	**End-Sem**	**TW**	**PR**	**OR**	**Total**	**TH**	**PR**	**Internship**	**Total**
311508(A)	Robot Programming	3			30	70				100	3			3
311509(A)	Artificial Intelligence for Robotics	3			30	70				100	3			3
311510(A)	Flexible Manufacturing Systems	3			30	70				100	3			3
311511(A)	Elective 2	3			30	70				100	3			3
311508(B)	Robot Programming Lab		2					25	25	50		1		1
311509(B)	Artificial Intelligence for Robotics LAB		2				25	25		50		1		1
311510(B)	Flexible Manufacturing Systems Lab		2				25			25		1		1
311511(B)	Elective 2 Lab		2						25	25		1		1
311512	Software Lab		2				50			50		1		1
311513	Internship			4			100			100			4	4
311514	Mandatory Audit Course 6	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	**12**	**10**	**4**	**120**	**280**	**200**	**50**	**50**	**700**	**12**	**5**	**4**	**21**

Abbreviations:

TH : Theory TW : Term Work PR : Practical
OR : Oral TUT : Tutorial

Elective 2:

I: Micro-Electro-Mechanical Systems
II: Humanoid Robots
III: Modeling and Simulation
IV: Swarm Intelligence in Robotics

Mandatory Audit Course 6: Students should select one of the following subjects as an Audit Course

I. Technical writing and communication skill
II. Energy Auditing and Management in Industries

Embedded System in Robotics

311501(A)

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 3 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Pre-requisites: Applied Electronics Engineering

Course Outcomes:

After successful completion of this course, the student will be able to

1. Describe the concept of embedded system, microcontroller, different components of microcontroller and their interactions.
2. Write a computer program to develop embedded solutions.
3. Program the ARM microcontroller to perform various tasks.
4. Develop embedded system applications using the key concepts of embedded systems such as I/O, timers, interrupts and interaction with peripheral devices

Unit 1: Fundamentals of Embedded System (6)

Basic structure of embedded systems: Power-supply, Sensors, A-D/D-A converters, processor and ASICs and Actuators, memory. Communication Interface, Real time operating systems, Safety and reliability, environmental issues. Ethical practice. Characteristics, advantages and disadvantages of embedded systems.

Unit 2: Embedded Hardware and Design (6)

Microcontroller Unit (MCU) 48, A Popular 8-bit MCU, Memory for Embedded Systems, Low Power Design, Pullup and Pulldown Resistors, Introduction to ARM-v7-M (Cortex-M3), ARM-v7-R (CortexR4) and comparison in between them. Embedded Product development life cycle, Program modeling concepts: DFG, FSM, Petri-net, UML 2

Unit 4: Embedded Serial Communication (6)

Study of basic communication protocols like SPI, SCI (RS232, RS485), I2C, 10 CAN, Field-bus (Profibus), USB (v2.0), Bluetooth, Zig-Bee, Wireless sensor network

Unit 3: Embedded system programming (6)

Embedded C-programming concepts, Constants, Variables & Data Types, Operators, Functions, Softwares, interfacing of LED, LCD, motors, and switches. Serial Communication Programming: Introduction to Serial Communication, Types of Serial Communication, and Description of SFR associated with Serial Communication, Programming of UART, Interfacing of ADC, sensor interfacing, embedded networking

Unit 5: Real Time Based Operating System(RTOS) (6)

POSIX Compliance , Need of RTOS in Embedded system software, Foreground/Background systems, multitasking, context switching, IPC, Scheduler policies, Architecture of kernel, task scheduler, ISR, Semaphores, mailbox, message queues, pipes, events, timers, memory management, RTOS services in contrast with traditional OS.

Unit 6: Linux Fundamentals & Device Driver Programming (6)

Linux Fundamentals, Linux Commands, VI Editors, Introduction to Device Driver, The Role of Device Driver, Kernel Module Vs Application, Types of Device Driver, Character Driver, Block Driver & network Driver.

Reference books:

1. K. V. Shibu, Introduction to Embedded Systems, TMH, ISBN: 978-9339219680
2. F. Vahid, Embedded System Design – A unified hardware and software introduction, John Wiley, ISBN: 978-0-471-38678-0
3. Rajkamal, Embedded Systems, TMH.
4. L. B. Das, Embedded Systems and Integrated approach, Pearson, ISBN: 978-81-317-8766-
5. M. Mazidi, PIC Microcontroller and Embedded System, Pearson

Hydraulics and Pneumatics

311502(A)

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

Prerequisites: Systems in Mechanical Engineering

Course Outcomes:

Students will be able to

1. Exemplify the basic principles of Industrial fluid power.
2. Select and specify various components for hydraulic and pneumatic systems.
3. Execute PLC program for electro-hydraulic circuit applications
4. Organize hydraulic and pneumatic circuits for given application
5. Evaluate the hydraulic and pneumatic systems based on various evaluation criteria

Unit I: Introduction to fluid power and automation (6)

Introduction to oil hydraulics and pneumatics, their structure, advantages and limitations. Properties of fluids, Fluids for hydraulic systems, governing laws.

Unit II: Hydraulic pumps and actuators Pumps (6)

Classification of pumps, Pumping theory of positive displacement pumps, construction and working of Gear pumps, Vane pumps, Piston pumps, fixed and variable displacement pumps, Pump performance characteristics, pump Selection factors, problems on pumps. Design of reservoir capacity. Classification cylinder and hydraulic motors, Linear Hydraulic Actuators [cylinders], single and double acting cylinder, Mechanics of Hydraulic Cylinder Loading, mounting arrangements, cushioning, special types of cylinders, problems on cylinders, construction and working of rotary actuators such as gear, vane, piston motors, Hydraulic Motor Theoretical Torque, Power and Flow Rate, Hydraulic Motor Performance, problems, symbolic representation of hydraulic actuators (cylinders and motors).

Unit III: Control Components in hydraulic system (6)

Classification of control valves, Directional Control Valves- Symbolic representation, constructional features of poppet, sliding spool, rotary type valves solenoid and pilot operated DCV, shuttle valve, check valves, Pressure control valves - types, direct operated types and pilot operated types. Flow Control Valves -compensated and non-compensated FCV, needle valve, temperature compensated, pressure compensated, pressure and temperature compensated FCV, symbolic representation.

Unit IV: Hydraulic Circuit Design and Analysis (6)

Control of Single and Double -Acting Hydraulic Cylinder, Regenerative circuit, Pump Unloading Circuit, Counter balance Valve Application, Hydraulic Cylinder Sequencing Circuits, Automatic cylinder reciprocating system, Speed Control of Hydraulic Cylinder and motors, Safety circuit, Accumulators, types, construction and applications with circuits, Intensifier circuits and their applications, Proportional control valves and servo valves.

Unit V: Introduction to Pneumatic system (6)

Introduction to Pneumatic Control: Definition of pneumatic system, advantages, limitations, applications, Choice of working medium. Characteristic of compressed air. Structure of Pneumatic control System, fluid conditioners and FRL unit. Pneumatic Actuators: Linear cylinder - Types, Cascade design of Pneumatic circuit, Use of Logic gates - OR and AND gates in pneumatic applications.

Unit VI: Electro-hydraulics and electro-pneumatic systems (6)

PLC based electro-hydraulic systems, PLC programming using ladder logic for automation and robotics applications, Electro-Pneumatic Control: Principles - signal input and output, pilot assisted solenoid control of directional control valves, Use of relay and contactors. Control circuitry for simple applications.

Reference books:

1. Esposito Anthony, Fluid power with Applications, Pearson, ISBN: 978-81-7758-580-3
2. Mujumdar S.R., Pneumatic Systems, Tata McGraw Hill, 2002 Edition. ISBN: 9780074602317
3. Bolton W., Mechatronics Electronic Control Systems in Mechanical and Electrical Engineering, Pearson, Education (Singapore) Pvt Ltd., ISBN 81-7808-339-6.
4. Industrial hydraulics manual by Vickers, Inc.
5. Fluid Power: Generation, Transmission and Control, Wiley, 2018, ISBN: 9788126539543
6. Peter Rohner, Industrial hydraulic control, Hydraulic Supermarket, 2005, ISBN 978-0958149310

Robot Kinematics and Dynamics

311503(A)

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Pre-requisites: Engineering Mechanics, Strength of Materials,

Course outcomes:

Student will be able to:

1. Select the type of mechanism for the robotic applications
2. Perform kinematic analysis, synthesis of mechanisms.
3. Perform forward and inverse kinematics of robots
4. Apply design procedure for mechanical grippers depending upon their types and mechanism
5. Design of robot manipulators based on dynamic analysis

Unit I: Robot Mechanisms **(6)**

kinematic Link ,Types of links, Kinematics pair, Types of constrained motion, Classification of Kinematics pairs, Kinematics chain, Degrees of freedom of mechanisms, Inversion of mechanism, Analysis of mechanisms such as Gear trains, cams and followers, belt drives, four bar mechanism, slider crank mechanism etc. Computer aided analysis and synthesis of coupler curves for four bar/five bar mechanism and slider crank mechanisms,

Unit II: Forward Kinematics **(6)**

Robot kinematics-Types- 2D, 3D Transformation, D-H Representation, Displacement Matrices for Standard Configurations, Forward kinematics of manipulators up to 6 degrees of freedom

Unit III: Inverse kinematics **(6)**

Inverse kinematics analysis of robot with standard configurations, methods for solution of non-linear simultaneous equations, use of meta-heuristics for inverse kinematic solutions

Unit IV: Robot end effectors: **(6)**

Types of end effectors, mechanical grippers, vacuum grippers, magnetic grippers, adhesive grippers, tools. force analysis, the robot end effectors interface, considerations in gripper selection and design.

Unit V: Robot Arm Dynamics **(6)**

Robot dynamics – Rigid body dynamics, Newton-Euler formation, Lagrange-Euler, formation, generalized D'Alembert equations of motion.

Unit VI: Balancing and Vibrations **(6)**

Static and Dynamic balancing, Balancing of revolving and reciprocating masses, Balancing machines, free vibrations, Equations of motion, natural Frequency, Damped Vibration, bending critical speed of simple shaft.

Reference books:

1. Hartenberg and Denavit, "Kinematics and Synthesis of Linkages", McGraw Hill Book Co.
2. J. E. Shigley and J.J.Uicker Jr., Theory of Machines and Mechanism, McGraw Hill [ISBN019515598X]
3. G K Grover', "Mechanical Vibration", Nemchand and brothers. [ISBN8185240752]
4. S.S.Ratan , Theory of Machines, Tata McGraw Hill [ISBN0070591202]
5. Deb S.R., ―RoboticsII, Tata McGraw Hill Publications, New Delhi.
6. YoramKoren, "Robotics for Engineers", McGraw Hill Book Co.
7. Groover M.P., Weiss M., Nagel R.N., Odrey N.G., "Industrial Robotics Technology-Programming and Applications", McGraw Hill Book Co.

Sensor Technology

311504(A)

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 3 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Pre-requisites: Applied Electronics Engineering

Course Outcomes:

After successful completion of this course, the student will be able to

1. Choose sensor for a particular application
2. Check the performance of the sensor under test.
3. Design signal conditioning circuitry for a sensor
4. Analyze the specifications of various types of sensors
5. Understand the principals of advance sensors

Unit I: Sensor Fundamentals (6)

Sensor Performance Characteristics, Types of Sensors Sensor Signal Conditioning, Conditioning Bridge Circuits, Amplifying and Linearizing Bridge Outputs, Amplifiers for Signal Conditioning, Precision Op Amp Characteristics, Instrumentation Amplifiers. Data-Acquisition Systems: Hardware and Software of Data Aquisition System (DAS)

Unit II: Mechanical Transducers (6)

Transduction methods, accelerometers, gyroscopes, pressure sensors, MEMS microphones, mechanical structures, actuators. Chemical and Biological Transducers: basic concepts of cellular biology, chemical sensors, molecule-based biosensors, cell-based biosensors, chemical actuators, biological transducers.

Unit III: Thermal Sensors (6)

Definition of Temperature: Thermal Energy, absolute and relative Temperature, Metal resistance versus temperature devices: Resistance versus Temperature Approximations, Resistance-Temperature Detectors (RTD), Thermistors, Semiconductor Resistance versus Temperature, Thermistor Characteristics, thermocouples, Thermoelectric Effects, Thermocouple, Characteristics, Thermocouple Sensors, Other thermal sensor: Bimetal Strips, Gas Thermometers.

Unit IV: Displacement, Location, or Position Sensors (6)

Resistive, Capacitive, and Inductive Sensors, Variable-Reluctance Sensors, LVDT, Level Sensors, Acceleration, Shock and Vibration Sensors: Piezoelectric Accelerometer, Piezo resistive Accelerometers, Applicable Standards, Interfacing and Designs, Latest Developments

Unit V: Force, Load and Weight Sensors (6)

Quartz Sensors, sensor types, Applicable Standards Strain Gage Sensors, types, Applicable Standards, Metal Strain Gauges and Semiconductor Strain Gauges (SGs), Load Cells

Unit VI: Optical and Radiation Sensors: (6)

Photo sensors, Thermal Detectors, Phototransistor, Position and Motion Sensors. Introduction to Nanotechnology-Enabled Sensors, Bio Sensors

Reference Books:

1. John Wilson: Sensor Technology Handbook.
2. "Process Control Instrumentation Technology, 6th Edition", Author: Curtis D. Johnson, Publisher: Prentice Hall International Edition, ISBN: 0-13-978-200-3
3. J. Fraden, Handbook of Modern Sensors:Physical, Designs, and Applications, AIP Press, Springer
4. D. Patranabis, Sensors and Transducers, PHI Publication, New Delhi
5. Ganesh S. Hegde, Mechatronics, University Science Press (An imprint of Laxmi Publication Private Limited).

Elective 1-Statistics and Numerical Methods

311505(A)-I

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Prerequisites: Engineering Mathematics- I, II and III, Design of Machine Elements

Course Outcomes:

Students will be able to

1. Understand the sampling and concept of hypothesis
2. Design the experiments based on the processes parameters.
3. Make use of numerical method to solve the simultaneous equations.
4. Able to establish the co-relation between input factors and performance measure using regression analysis and interpolation methods
5. Make use of numerical & iterative methods for solving complex algebraic & transcendental equation, simultaneous equations, curve fitting, interpolation , optimization , integration & differentiation

Unit I: Statistical hypothesis and tests **(6)**

Testing of Hypothesis Sampling distributions - Estimation of parameters, Statistical hypothesis, Large sample tests based on Normal distribution for single mean and difference of means,-Tests based on t, Chi-square and F distributions for mean, variance and proportion - Contingency table (test for independent) - Goodness of fit

Unit II: Design and Analysis of Experiments **(6)**

Design and Analysis of Experiments: Importance of experiments, Experimental strategies, Basic Principles of Design Terminology, ANOVA, steps in experimentation, two and three full Factorial experiments, Taguchi Methods, Design using Orthogonal Arrays, S/N ratios, Data Analysis

Unit III: Numerical Solutions of algebraic, transcendental and Linear Simultaneous Equations **(6)**

Errors and error propagation in numerical techniques, Numerical solution of algebraic and transcendental equations: Bisection method, Newton Raphson Method. Numerical solution of Linear Simultaneous Equations: Gauss Elimination Method, Gauss-Seidel Method.

Unit IV: Methods of curve fitting **(6)**

Numerical methods - Curve Fitting, methods of curve fitting. Least square criterion- 1st and 2nd order Interpolation: Lagrange's formula, Newton forward difference method. Methods of moment for curve fitting, Interpolation techniques: Newtons forward difference method, Lagrange interpolation polynomial.

Unit V: Numerical Differentiation and integration **(6)**

Numerical single and double integrations using Trapezoidal and Simpson's 1/3 rules, Ordinary Differential Equations: Runge-Kutta Method. Partial Differential Equations -Finite difference method

Unit VI: Optimization Methods **(6)**

Manufacturing Optimization- Gradient methods, Method of Lagrange multipliers, Generalized reduced gradient Method. Introduction to GA and SA. Case studies in robotic applications.

Reference Books:

1. Douglas C. Montgomery, Design and analysis of experiments, John Wiley and sons Inc. New York 8th edition.
2. S.C. Chapra, R.P. Canale, ―Numerical Methods for engineers with programming and software applications, Tata McGraw Hill Co. Ltd, New Delhi, ISBN 0071158952.
3. Dr. Sadhu Singh, ―Computer aided Design and Manufacturingll, Khanna Publication, New Delhi.
4. Ramin S. Esfandiari, Numerical Methods for Engineers and Scientists Using MATLAB, CRC press, Taylor and Francis group.
5. Jaan Kiusalaas, Numerical Methods in Engineering with Matlab, Cambridge University press.
6. S. S. Rao, Engineering Optimization: Theory and Practice, New Age International, 2000, ISBN: 9788122411492

Elective 1-Finite Element Analysis

311505(A)-II

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 03 hours / week	Theroy: 03	In-Sem: 30 Marks
		End-Sem: 70 Marks

Prerequisites: Fundamentals of Programming Language, Engineering Mechanics, Strength of Material, Kinematics of Manufacturing Machines, Design of Machine Elements, Heat and Fluid Engineering

Course Outcomes

After successful completion of course student will able to:

1. Model and Analyze 1-D problem.
2. Model and Analyze Truss subjected to loading
3. Model and Analyze Two-Dimensional Problem Using Constant Strain Triangles
4. Perform finite element modeling of triangular element and 2-D iso-parametric elements
5. Analyze steady state heat transfer - 1D and 2D heat conduction and convection
6. Identify meshing techniques quality aspects of meshing

Unit I: Introduction (6)

Introduction, One Dimensional Problem, Finite Element modeling, Coordinate and Shape function, Derivation of stiffness matrix and Load Vector using Potential Energy approach, Properties of Stiffness Matrix, Assembly of Global Stiffness Matrix and Load Vector, Elimination and penalty approach, shape function, Quadratic Shape Function.

Unit II: Trusses (6)

Introduction to different approaches used in FEA such as direct approach, Variational approach, weighted residual, energy approach, Galerkin and Raleigh Ritz approach, Introduction to Plane trusses, Assembly of global Stiffness Matrix for Banded Skyline solutions.

Unit III: Two-Dimensional Problem Using Constant Strain Triangles (6)

Introduction, finite element formulation, load considerations and boundary conditions, problem modeling, member end forces, plane frame.

Formulation of elemental stiffness matrix and load vector for Plane stress/strain such as Linear Strain Rectangle (LSR), Constant Strain Triangles (CST), Pascal's triangle , primary and secondary variables, properties of shape functions.

Unit IV: A**xi-symmetric solids subjected to axi-symmetric loading** (6)

Introduction, axi-symmetric formulation, finite element modeling of triangular element

Two dimensional iso-parametric elements

Introduction, four node quadrilateral, introduction to higher order elements.

Unit V: Finite element analysis of heat transfer (6)

Introduction, steady state heat transfer - 1D and 2D heat conduction and convection, governing differential equation, boundary conditions, formulation of element.

Unit VI: Dynamic analysis (6)

Types of dynamic analysis, General dynamic equation of motion, point and distributed mass, lumped and Consistent mass, Mass matrices formulation of bar and beam element. Undamped-free vibration- Eigenvalue problem, Evaluation of eigenvalues and eigenvectors (natural frequencies and mode shapes).

Reference Books

1. R. D. Cook, et al., "Concepts and Applications of Finite Element Analysis" Wiley, India
2. Chandrupatla T. R. and Belegunda A. D., ―Introduction to Finite Elements in Engineering‖, Prentice Hall India.
3. Seshu P., ―Text book of Finite Element Analysis, PHI Learning Private Ltd. New Delhi, 2010.
4. Bathe K. J., ―Finite Element Procedures‖, Prentice-Hall of India (P) Ltd., New Delhi.
5. Fagan M. J., ―Finite Element Analysis, Theory and Practice‖, Pearson Education Limited
6. Kwon Y. W., Bang H., ―Finite Element Method using MATLAB‖, CRC Press, 1997
7. S. Moaveni, ―Finite element analysis, theory and application with Ansys,
8. David V. Hutton, Fundamental of Finite Element Analysis, Tata McGraw-Hill

Elective 1-Industrial Robotics and Material handling Systems

311505(A)-III

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 3 hours / week	Theory:03	In-Sem: 30 Marks End-Sem : 70 Marks

Course Outcomes:

Students will be able to

- Describe the material handling system
- Explain storage and data capturing system
- Distinguish parts of robots and types of robots.
- Select the robots according to its usage.
- Describe various applications of robots, justification and implementation of robot.

Unit I: Introduction to Material handling (6)

Principles of Material Handling, Unit load concept, Material Handling equipment, Material transport systems: AGVs, Monorails, Conveyor systems, Cranes and hoists, Analysis of material transport systems: Charting technique, analysis of vehicle based systems, Conveyor analysis

Unit II: Storage and Data capturing systems (6)

Conventional storage methods and equipments Storage system performance, Analysis of Automated storage/retrieval systems (ASRS) and Carousel Storage system.
Automatic data capturing system (ADC), Bar coding, Radio frequency identification (RFID), Optical character recognition, Magnetic stripes

Unit III: Introduction Industrial Robots (6)

Types of industrial robots, Load handling capacity, general considerations in Robotic material handling, material transfer, machine loading and unloading, CNC machine tool loading, Robot centered cell.

Unit IV: End Effectors (6)

Classification, Design consideration, Materials for hostile operation. Cylindrical Cam type;Grippers using pneumatic, hydraulic and electrical motor for transmission; Vacuum Grippers,Ultrasonic grippers.

Gripper force analysis and gripper design, design of multiple degrees of freedom, active and passive grippers. Selection of Robot: Factors influencing the choice of a robot, robot performance testing, economics of robotisation, Impact of robot on industry and society.

Unit V: Applications of Robots in Manufacturing (6)

Pick and place Robot, Application of Robots in Arc Welding Robots, Assembly and mega-assembly Robots continuous arc welding, Spot welding, Spray painting, assembly operation,

Other industrial applications: Coating, Deburring, cleaning,Die Casting, Moulding, Material handling, Picking, Palletizing, Packaging

Robots For Inspection : Robotic vision systems, image representation, object recognition and categorization, depth measurement

Unit VI: Advanced Applications of robots (6)

Military and medical applications, robot for underwater applications Robots, Climbing Robots, Machine mounted Robots. Interfacing Robots with computers. Obstacle Avoidance: Lee's Algorithm; Counter Path Defining using 'via' point, blending

Reference Books

1. M. P. Groover, “Automation, Production Sysytems, and Computer –Integrated Manufacturing”, Pearson Education,ISBN-81-7808-511-9
2. Deb S.R., “Robotics”, Tata McGraw Hill Publications, New Delhi.
3. Yoram Koren, "Robotics for Engineers", McGraw Hill Book Co.
4. Groover M.P., Weiss M., Nagel R.N., Odrey N.G., "Industrial Robotics Technology - Programming and Applications", McGraw Hill Book Co.
5. Fu K.S., Gonzalex R.C., Lee C.S.G., "Robotics Control Sensing, Vision and intelligence", McGraw Hill Book Co.
6. Hartenberg and Denavit, "Kinematics and Synthesis of Linkages", McGraw Hill Book Co.
7. Hall A.S., "Kinematics and Linkage Design", Prentice Hall.
8. Hirchhorn J., "Kinematics and Dynamics of Machinery", McGraw Hill Book Co.
9. Todd D.J., “Fundamentals of Robot Technology”, Wiley Publications
10. Paul R., “Robots - Manipulators, Mathematics, Programming and Control”, MIT Press.
11. Janakiraman P.A., “Robotics and Image Processing”, Tata McGraw Hill 1995.
12. Rudenko N., “Material, Handling equipment”, MIR Publications, Moscow.
13. Jacob Fruchlboum, “Bulk Material Handling Handbook”, 1st Edition, Springer, 1988
14. Monkman, G. J.; Hesse, S.; Steinmann, R.; Schunk*, H, “* Robot Gripper” *Wiley-VCH. p. 62.* ISBN 978-3-527-40619-7

Elective 1-Intelligent Manufacturing System

311505(A)-IV

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 03 hours / week	Theroy: 03	In-Sem: 30 Marks
		End-Sem: 70 Marks

Pre-requisites: Numerical techniques and optimization methods, Process Planning and Tool Selection, Industrial Engineering and Management, Production Management

Course Outcomes:
After learning this subject, the student will be able to:

Implement statistical methods, evolutionary optimization techniques, soft computing methods, machine learning and knowledge based system for manufacturing system applications such as:

1. Equipment selection and layout
2. Process planning and parametric optimization
3. Cellular manufacturing
4. Robotics systems

Unit I: Introduction to artificial intelligent techniques (6)

Goals of AI in manufacturing, tools for AI such as Search algorithm, Mathematical optimization,Evolutionary computation, fuzzy logic, Probabilistic methods for uncertain reasoning such as Bayesian network, Hidden Markov model, Kalman filter, Decision theory and Utility theory, statistical learning methods, support vector machines, neural networks, expert systems

Unit II: Industrial planning and decision making using intelligent systems (6)

Production planning using fuzzy cognitive maps, computer aided process planning, Methods for inventory space allocation and storage processes analysis, Optimization of production costs and methods finding of the best process plan, Methods for production equipment selection and layout, Heuristic scheduling of multiple resources, Fuzzy multiple attribute decision making methods.

Unit III: Intelligent techniques for manufacturing process optimization (6)

Application of neural networks and fuzzy sets to machining and metal forming, Artificial neural network modeling of surface quality characteristics in machining processes, parametric optimization of machining processes using evolutionary optimization methods**.**

Unit IV: Knowledge Based Group Technology (6)

Group Technology: Models and Algorithms – Visual method, Coding method, Cluster analysis method Knowledge based group technology – Group technology in automated manufacturing system, Structure of knowledge based system for group technology (KBSGT) –database, knowledge base, Clustering algorithms

Unit V: Intelligent robotic systems (6)

Applications of intelligent systems for mobile Robot Motion Planning, Path Planning Robot Control in Dynamic Environments, Task Based Hybrid Closure Grasping Optimization for Autonomous Robot Hand. Accurate Motion Control of Fast Mobile Robots, obstacle avoidance.

Unit VI: Use of Intelligent techniques in flexible manufacturing systems (FMS) (6)

Applications of various intelligent systems for FMS functional segmentation schemes including control, real time scheduling, tool management, process planning, route optimization for AS/RS systems.

Reference books:

1. Andrew Kusiak, “Intelligent Manufacturing Systems”, Prentice Hall , 1990
2. Badiru A.B., “Expert Systems Applications in Engineering and Manufacturing”, Prentice-Hall, New Jersey, 1992.
3. Liu, Dikai, Wang, Lingfeng, Tan, Kay Chen (Eds.) Design and Control of Intelligent Robotic Systems, Springer-Verlag, London. ISBN 978-3-540-89932-7
4. Rao R. V. “Advanced Modeling and Optimization of Manufacturing Processes”, Springer-verlag, London. ISBN 978-0-85729-014-4

Embedded systems in Robotics Lab

311501(B)

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Practical: 02 hours / week	Practical: 01	TW: 25 Marks

List of Practical

1. Porting of µC/OS II on ARM7/Cortex controller.
2. Implementation/Verification of multitasking (minimum 03 tasks) with µC/OS II on ARM7/Cortex controller.
3. Implementation of semaphore with µC/OS II service ARM7/Cortex controller for resource management and synchronization.
4. Implementation of inter process communication with ucos-II mailbox and message queue service on ARM7/Cortex controller.
5. Programming with exploring on chip ADC of Cortex /MSP430 based microcontroller.
6. Programming on motor control with exploring on chip PWM of Cortex based microcontroller.
7. Exercise on Porting of Linux on ARM board (ARM9 preferably)
8. Programming for device driver with Embedded Linux.

Hydraulics and Pneumatics Lab

311502(B)

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Practical: 02hours / week	Practical: 01	PR: 25 Marks

List of Practical

1. Experiment on measurement of hydraulic pump efficiency
2. Experiment on design of speed control hydraulic circuits.
3. Experiment on design of regenerative circuits
4. Experiment on design of electro-hydraulic sequencing circuits
5. Experiment on pneumatic circuits by demonstrating logic gates.
6. Experiment on electro-pneumatic circuits
7. Experiment on programmable logic controllers: Ladder logic programming
8. Microprocessor programming for basic operations.
9. Industrial visit report on automation in any Industry

Robot Kinematics and dynamics Lab

311503(B)

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 02 hours / week	Practical: 01	Term Work: 25 Marks PR: 25 Marks

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Term work will be based on following practical/design assignments

1. To write a computer program for analysis of any mechanism and test it.
2. Determination of holding torque in epicyclic gear train.
3. Design of cams and followers
4. Experiment on Robot forward kinematic analysis
5. Experiment on Robot inverse kinematic analysis
6. Determination of mass moment of inertia and radius of gyration of robotic links
7. Experiment on balancing of mass

Sensor Technology Lab

311504(B)

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 02 hours / week	Practical: 01	OR: 25 Marks

List of Experiments:

1. Design of instrumentation amplifier
2. Measurement of temperature using thermistor (whetstone Bridge)
3. Measurement and Analysis of temperature using various sensors.
4. Measurement of Displacement using LVDT.
5. Measurement and Analysis of Displacement using various sensors.
6. Measurement of load using strain gauge.
7. Measurement and Analysis of load using various sensors.
8. Study of photo sensors.

Elective 1-Statistics and Numerical Method Lab

311505(B)-I

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Practical: 02hours / week	Practical: 01	OR: 25 Marks

Each candidate shall be required to complete and submit the following term work.

1. Practical on parameter optimization of any one process using Taguchi based design of experiment. Validation of results using any statistical software (R/ Minitab/ Excel/ SigmaXL/ Statgraphics etc.).
2. Practical on determination of significant factors for any one process using ANOVA. Validation of results using any statistical software. (R/ Minitab/ Excel/ SigmaXL/ Statgraphics etc.).
3. Practical case study on regression analysis. (Data should be collected for some real life case). Validation of results using any statistical software. (R/ Minitab/ Excel/ SigmaXL/ Statgraphics/ Matlab etc.).
4. Practical case study on regression analysis. (Data should be collected for some real life case).
5. Practical case study on multivariable optimization with constraint using any one method.
6. C programming for any 3 practical mentioned above.

Elective 1-Finite Element Analysis Lab

311505(B)-II

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 02 hours / week	Pr/Or: 01	OR: 25 Marks

Term work will be based on following Practical work

1 Computer program for axial bar subjected to axial forces.

2 Computer program for truss subjected to plane forces.

3 Computer program for beams subjected to transverse forces and moments

4 Computer program for frames subjected to transverse forces and moments

5 Stress and deflection analysis of two dimensional truss using FEA software

6 Stress and deflection analysis of any machine component consisting of 2-D elements using FEA software.

7 Stress and deflection analysis of any machine component consisting of 3-D elements using FEA software

8 Modal analysis of any machine components.

9 Computer program for 1-D temperature analysis

10 Thermal analysis of member subjected to loading

11 Shear force and Bending Moment Calculations of Shaft using FEA software

12 Analysis of component subjected to self weight

13 Thermal analysis of composite wall

Elective 1-Industrial Robotics and Material handling Systems Lab

311505(B)-III

Teaching Scheme	Credit Scheme	Examination Scheme
Practical:2 hours / week	Practical: 01	OR: 25 Marks

Term Work

The term work shall be based on the following assignments:

1. Study of Material handling systems
2. Study and analysis of Storage and Data capturing systems
3. Study of configuration of robots and motion of robot manipulator
4. Study of pick and place industrial robot
5. Study and analysis of robot grippers (includes the problems based on gripper force)
6. Case Study on advanced industrial applications of robots

Elective 1-Intelligent Manufacturing System Lab

311505(B)-IV

Teaching Scheme	Credit Scheme	Examination Scheme
Practical:2 hours / week	Practical: 01	OR:25 Marks

Term Work

Term work will be based on following assignments:

1. Study of Artificial Intelligent techniques with application examples
2. Case studies on industrial decision making using fuzzy multiple attribute decision making
3. Applications of artificial neural networks to manufacturing engineering
4. Study of various clustering algorithms for group technology
5. Study of algorithms for robot path planning/obstacle avoidance
6. Case study on route optimization of AS/RS systems

Seminar

311506

Teaching Scheme	Credit Scheme	Examination Scheme
Seminar:1 hours / week	Seminar: 01	Term work: 50 Marks

1. The objective of Seminar is to test the student on his/her ability for self-study and his/her ability to communicate - Written and oral.
2. Seminar will be in the form of a report submitted by the student:
   a) On topic of his/her choice based on literature survey/ a case study wherever applicable/possible, and approved by the staff- in- charge.
   b) A report with 20-25 pages of A-4 size paper, 1.5 spaced typed material, and appropriately bound.
   c) Title font/figures/graphs shall be black and white.

Audit Course 5:
Disaster Management
311507

The course is intended to provide a general concept in the dimensions of disasters caused by nature beyond the human control as well as the disasters and environmental hazards induced by human activities with emphasis on disaster preparedness, response and recovery.

Course Contents:

1. Different Types of Disaster: Natural and man made
2. Risk and Vulnerability Analysis
3. Disaster Preparedness
4. Disaster Response
5. Reconstruction and Rehabilitation as a Means of Development.
6. Damage Assessment
7. Post Disaster effects and Remedial Measures.
8. Long-term Counter Disaster Planning

Mandatory Audit Course 5:
Industrial Waste management
311087

Introduction: Characteristics of industrial wastes, Types of industries and industrial pollution, Population equivalent, Bioassay studies, effects of industrial effluents on streams, sewer, land, sewage treatment plants and human health, Environmental legislations related to prevention and control of industrial effluents and hazardous wastes.

Waste management Approaches: Waste Audit, Volume and strength reduction, Material and process modifications, Recycle, reuse and byproduct recovery – Applications.

Treatment technologies: Equalization, Neutralization, Removal of suspended and dissolved organic solids, Chemical oxidation, Adsorption, Removal of dissolved inorganics, combined treatment of industrial and municipal wastes, Residue management, Dewatering, Disposal

Reference books:

1. Zander Elis,, Industrial Waste Management, Larsen and Keller Education, 2017, ISBN: 9781635491494
2. John P. Samuelson, Industrial Waste: Environmental Impact, Disposal and Treatment, Nova Science Publishers, 2009, ISBN: 9781606927205

Robot Programming

311508(A)

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Pre-requisites: Sensors Technology, Robot Kinematics and dynamics.

Course outcomes:

Student will be able to:

1. Explain robot programming methods
2. Classify the components of robot programming
3. Develop simple programs to simulate robot movements
4. Develop robot programs for specific application
5. Describe the safety rules in robot handling

UNIT 1: Introduction to Robot Programming (6)

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

UNIT 2: VAL Language (6)

Robot Languages-Classifications, Structures- VAL language commands motion control, hand control, program control, pick and place applications, palletizing applications using VAL, Robot welding application using VAL program-WAIT, SIGNAL and DELAY command for communications using simple applications.

UNIT 3: VAL-II (6)

VAL-II programming-basic commands, applications- Simple problem using conditional statements-Simple pick and place applications-Production rate calculations using robot.

UNIT 4: RAPID Language (6)

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

UNIT 5:AML Language (6)

AML Language - General description, elements and functions, Statements, constants and variables-Program control statements-Operating systems, Motion, Sensor commands-Data processing.

UNIT 6: Practical Study of Virtual Robot (6)

Robot cycle time analysis-Multiple robot and machine Interference-Process chart-Simple problems-Virtualrobotics, Robot studio online software- Introduction, Jogging, components, work planning, program modules, input and output signals-Singularities-Collision detection-Repeatability measurement of robot-Robot economics. AML Language-General description, elements and functions, Statements, constants and variables-Program control statements-Operating systems, Motion, Sensor commands-Data processing.

Reference Books:

1. S. R.Deb, Robotics technology and flexible automation, Tata McGraw Hill publishing company limited, 1994.
2. Mikell. P. Groover, Industrial Robotics Technology, Programming and Applications, McGraw HillCo, 1995.
3. Robotcs Lab manual, 2007.
4. Klafter. R.D, Chmielewski.T.A. and Noggin's., Robot Engineering : An Integrated Approach,Prentice Hall of India Pvt. Ltd.,1994.
5. Fu. K. S., Gonzalez. R. C. & Lee C.S.G., Robotics control, sensing, vision and intelligence, McGrawHill Book co, 1987.
6. Craig. J. J. Introduction to Robotics mechanics and control, Addison-Wesley, 1999.

Artificial Intelligence for Robotics

311509(A)

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

Pre-requisites: Engineering mathematics-III, statistics and Numerical Methods, Sensors Technology

Course outcomes:

Student will be able to:

1. Select appropriate artificial intelligence method/algorithm to handle various issues in robotics
2. Demonstrate various algorithms used in artificial intelligence
3. Apply artificial intelligence algorithms to robotics problems
4. Compare the performance of AI algorithms
5. Build solution methodology to solve complex problems in flexible automation

Unit I: Introduction to artificial intelligent techniques (6)

Goals of AI in manufacturing, tools for AI such as Search algorithm, Mathematical optimization, Evolutionary computation, fuzzy logic, Probabilistic methods for uncertain reasoning such as Bayesian network, Hidden Markov model, Kalman filter, Decision theory and Utility theory, statistical learning methods, support vector machines, neural networks, expert systems

Unit 2: Handling uncertainty and learning: (6)

Non-monotonic reasoning, probabilistic reasoning, use of certainty factors, fuzzy logic, Concept of learning, learning automation, genetic algorithm, learning by inductions, neural network, Unsupervised learning- K-Means clustering, Boltzmann machine, Supervised learning-classification algorithms, support vector machine.

UNIT 3: Search algorithms in AI: (6)

Algorithms for uninformed and informed search, Heuristics search: hill climbing, branch and bound, best first search, Metaheuristics: Simulated annealing, Tabu search, ant colony optimization, real coded genetic algorithm.

Unit 4: Machine vision in robotics: (6)

Machine vision algorithms, Imaging based automatic sorting and inspection, image processing, imaging based robot guidance,

Unit 5: Intelligent robotic systems (6)

Applications of intelligent systems for mobile Robot Motion Planning, Path Planning Robot Control in Dynamic Environments, Task Based Hybrid Closure Grasping Optimization for Autonomous Robot Hand. Accurate Motion Control of Fast Mobile Robots, obstacle avoidance.

Unit 6: Artificial intelligence in flexible automation (6)

Applications of various intelligent systems for FMS functional segmentation schemes including control, real time scheduling, tool management, process planning, route optimization for AS/RS systems.

References:

1. Steger, Carsten, Markus Ulrich, Christian Wiedemann. Machine Vision Algorithms and Applications (2nd ed.). Wiley, 2018. ISBN 978-3-527-41365-2.
2. Mikell P Groover, Automation, Production System and Computer Integrated Manufacturing, Prentice Hall, Publications, 2016. ISBN 9789332549814
3. Bhattacharya S., Artificial Intelligence, Laxmi Publications, Ltd., 2008, ISBN9788131804896
4. Chopra Rajiv, Artificial Intelligence, S. Chand Publishing, 2012, ISBN9788121939485
5. Pawar P. J., Evolutionary Computations for Manufacturing, Studium Press, 2019, ISBN: 978-93-85046-52-0
6. Ramesh Jain, Rangachar Kasturi, Brian G. Schunck, Machine Vision, McGraw-Hill, Inc., 1995, ISBN 0-07-032018-7,

Flexible Manufacturing Systems

311510(A)

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Pre-requisites: Industrial Engineering and Management, Manufacturing Technology

Course outcomes:

Students should be able to:

1. Describe FMS and its applications.
2. Implement GT.
3. Perform CNC programming
4. Apply the concept of computer integrated manufacturing in FMS scenario
5. Understand basics of Tool Management System.

Unit I: FMS Introduction and Description (6)

limitations with conventional manufacturing, Need for FMS Introduction, Definition, Basic Component of FMS, Significance of FMS, General layout and configuration of FMS, Principle Objectives of FMS, Benefits and limitations of FMS, Area of Application of a FMS in Industry, Various Hardware and Software required for an FMS, CIM Technology, Hierarchy of CIM, FMS Justification

Unit II: Cellular Manufacturing (6)

Group Technology: Introduction, Definition, Reasons for Adopting Group Technology, Benefits of Group Technology Affecting Many Areas of a Company, Obstacles to Application of GT

Cellular Manufacturing Systems: Introduction, Description and Classifications of Cell, Unattended Machining, Cellular versus Flexible Manufacturing.

Unit III: Computer Aided Manufacturing (CAM) (6)

Concepts and features of NC, CNC & DNC - feed back devices ,Interpolators., Point-to-point and contouring systems – Interchangeable tooling system – preset & qualified tools – ISO specification – Machining center – Turning center,

CNC Programming: -Machine Tool Co-ordinate System, Machine zero, Job zero, Cutter Programming, Tool Offsets,

Manual part programming – steps involved – G-codes and M-codes, sample program in lathe & milling. CAM package – canned cycles - Programming.

Unit IV: Computer Integrated Manufacturing (CIM) (6)

Computer application in manufacturing automation, Computer aided inspection and quality control. Computer integrated production management system, inventory, material requirement planning, manufacturing resource planning, enterprise resource planning. Rapid Product Development and Manufacture, Extended Enterprises.

Unit 5: Automated Material Movement and Storage System (6)

Introduction, Types of AGV and Their principle of working, Advantages, Limitation and General AGV Guide path, Robots, Benefits of using Industrial Robots, Basic components and benefits of Automated Storage and Retrieval Systems, Conveyors and Pallet Flotation System, Queuing Carrousels and Automatic Work Changers, Coolant and Chip Disposal and Recovery system.

Unit 6: Cutting Tools and Tool Management (6)

Introduction, Control of Cutting Tools, Tool Management, Tool Strategies, Tool Preset, Identification and Data Transfer, Tool Monitoring and Fault Detection

Reference books:

1. H. K. Shivanand, M. M. Benal, Flexible Manufacturing System, New Age Pub.
2. Groover M.P, Automation, Production Systems and Computer Integrated Manufacturing, Prentice Hall of India,
3. Groover M.P, Zimmers E.W, CAD/CAM: Computer-aided Design and Manufacturing, Prentice Hall of India,
4. Nanua Singh, Approach to Computer Integrated Design and Manufacturing, John Wiley and Sons,
5. Vajpayee, S. Kant, Principles of Computer integrated Manufacturing, PHI,
6. Luggen W. W., Flexible Manufacturing Cells and Systems, PHI.

Elective 2-Micro-electro-mechanical Systems

311511(A)-I

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Pre-requisites: Applied Electronics Engineering**,** Sensor Technology

Course outcomes:

Students should be able to:

1. Recognize the operation of micro devices, micro systems and their applications
2. Design the micro devices, micro systems using the MEMS fabrication process.
3. Apply basic approaches for various sensor design
4. Apply basic approaches for various actuator design

Unit I: Introduction to MEMS **(6)**

What is MEMS? , Definition and Classification, History of MEMS, Intrinsic Characteristics of MEMS: Minitiarization, Microelectronics Integration, Parallel Fabrication with precision, Sensors and Actuator:Energy domains and transducers , Sensor Consideration, Actuator Consideration, Review of Electrical and Mechanical Concepts: Semiconductor devices ,Stress and strain analysis ,Flexural beam bending, Torsional deflection.

Unit II: Microfabrication **(6)**

Overview of Microfabrication : Photolithography, Thin film Deposition, Thermal oxidation of Silicon, wet etching, Silicon anisotropic etching, wafer dicing, wafer bonding etc., The Microelectronics Fabrication Process Flow , Silicon-Based MEMS Processes, New Materials and Fabrication Processes, LIGA Process , Assembly of 3D MEMS , Foundry process.

Unit III: Sensors and actuators I **(6)**

Electrostatic sensors, Parallel plate capacitors, Applications, Inter-digitated Finger capacitor, Comb drive devices, Micro Grippers, Micro Motors , Thermal Sensing and Actuation , Thermal expansion ,Thermal couples , Thermal resistors , Thermal Bimorph ,Applications , Magnetic Actuators , Micromagnetic components , Case studies of MEMS in magnetic actuators, Actuation using Shape Memory Alloys

Unit IV: Sensors and actuators II **(6)**

Piezoresistive sensors , Piezoresistive sensor materials , Stress analysis of mechanical elements , Applications to Inertia, Pressure, Tactile and Flow sensors ,Piezoelectric sensors and actuators , piezoelectric effects, piezoelectric materials , Applications to Inertia , Acoustic, Tactile and Flow sensors.

Unit V: Polymer and Optical MEMS **(6)**

Polymers in MEMS, Polimide ,SU-8 , Liquid Crystal Polymer (LCP), PDMS, PMMA, Parylene , Fluorocarbon, Application to Acceleration, Pressure, Flow and Tactile sensors. Optical MEMS ,Lenses and Mirrors , Actuators for Active Optical MEMS.

Unit VI: Case Studies of Selected MEMS products **(6)**

Blood pressure sensor, Microphone, Acceleration sensors, Gyros, Zigbee, Ultrasonic Distance ranging sensors, Metal Detector, Wireless Cameras and voice transmissions etc.

Reference books:

1. Nadim Maluf," An Introduction to Micro Electro Mechanical System Design", Artech House, 2000.
2. Mohamed Gad-el-Hak, editor, "The MEMS Handbook", CRC press Baco Raton, 2001.
3. Julian w. Gardner, Vijay K. Varadan, Osama O. Awadelkarim, Micro Sensors MEMS and Smart Devices, John Wiley & Son LTD, 2002.

4. James J.Allen, Micro Electro Mechanical System Design, CRC Press Publisher, 2005.
5. Thomas M.Adams and Richard A.Layton, “Introduction MEMS, Fabrication and Application,” Springer, 2010.
6. Chang Liu, ‘Foundations of MEMS’, Pearson Education Inc., 2012.
7. Stephen D Senturia, ‘Microsystem Design’, Springer Publication, 2000.
8. Tai Ran Hsu, “MEMS & Micro systems Design and Manufacture” Tata McGraw Hill, New Delhi, 2002.

Elective 2-Humanoid Robots

311511(A)-II

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Prerequisites: Kinematics and design of robots

Course outcomes:

After completion of the course, the students will be able to:

1. Identify characteristics of humanoid robots
2. Perform kinematics and dynamics analysis of humanoid robot
3. Apply algorithms to emulate neuro mechanism with humanoid robots
4. Design and build humanoid robots for simple applications

Unit I: Introduction to Humanoid Robots (6)

Historical development, trends in humanoid robots, design-human likeness, trade off in humanoid robot design, human friendly humanoid robot design, characteristics of humanoid robots

Unit II: Kinematics of Humanoid Robots (6)

Coordinate Transformations, Characteristics of Rotational Motion, Robot Data Structure and Programming, Kinematics of a Humanoid Robot: forward and inverse kinematics, Numerical Solution to Inverse Kinematics, Inverse Kinematics with Singularity Robustness

Unit III: Dynamics of Humanoid Robots (6)

Angular Momentum and Inertia Tensor of Rigid Body, zero moment point –measurement, 2D analysis, 3D analysis, derivation and calculation, 3D Walking Pattern Generation, ZMP Based Walking Pattern Generation, Dynamic Simulation

Unit IV: Humanoid robots and neuroscience: (6)

Humanoid Robotics Perspective to Neuroscience, Emulating the Neuro-Mechanisms with Humanoid Robots, Foveal Vision for Humanoid Robots, Humanoid Locomotion and the Brain, Cognitive Humanoid Robots

Unit V: Co-operative object manipulation and control (6)

Multi-fingered grasping, multi-arm object manipulation control, co-operation between multiple humanoids, leader follower type co-operative object manipulation, symmetry type co-operative object manipulation

Unit VI: Humanoid robots applications (6)

Search and rescue humanoid robots, service humanoids, sports humanoids, AI humanoid robots,

Reference Books:

1. Shuuji Kajita, Hirohisa Hirukawa, Kensuke Harada, Kazuhito Yokoi, Introduction to Humanoid Robotics, Springer, ISBN: 9783642545368

2. Gordon Cheng, Humanoid Robotics and Neuroscience: Science, Engineering and Society, CRC Press
3. Nenchev D. N., Konno a., Tsujita T, 'Humanoid robots-Modeling and Control' Butterworth Heinemann Publishing, ISBN: 9780128045602
4. S. L. Hamilton, Humanoid Robots, Abdo Publishing, ISBN: 9781532171437

Elective 2-Modeling and Simulation

311511(A)-III

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Pre-requisites: Machine Drawing, Engineering Mathematics III

Course Outcomes:
Students will be able to

1. Solve the problems based on simulation principal
2. Differentiate the simulation systems.
3. Collect data and generate the random numbers.
4. Distinguish simulations with regard to output analysis
5. Apply simulation to manufacturing system.
6. Handle software packages – ARENA/SimFactory/Promodel/ Witness

Unit I: Principles of Simulation and Modeling (6)

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 II: System Simulation (6)

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.

Unit III: Input Data Analysis (6)

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 IV: Random Variate Generation (6)

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 V: Simulation of Manufacturing Systems (6)

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 VI: Simulation Software **(6)**

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

Reference Books:

1. Averill M Law, "Simulation Modeling and Analysis", Fourth Edition, Tata McGraw Hill
2. Banks, J., J. S. Carson II, and B. L. Nelson. "Discrete-Event System Simulation", Second Edition,Prentice Hall,
3. Bratley, P., B. L. Fox, andL. E. Schrage "A Guide to Simulation", 2nd ed., Springer-Verlag, New York
4. Fishman, G.S., "Monte Carlo: Concepts, Algorithms and Applications", Chapman &Hall, New York.

Elective 2-Swarm Intelligence in Robotics

311511(A)-IV

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 03 hours / week	Theory: 03	In-Sem: 30 Marks End-Sem: 70 Marks

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Pre-requisites: Engineering mathematics III, Statistics and numerical methods

Course Outcomes:

After learning the subject student will be able to:

1. Explain the working mechanisms of various swarm intelligence algorithms
2. Tune the algorithm specific parameters of various swarm intelligence algorithms for any given application
3. Analyse the convergence behaviour of various swarm intelligence algorithms
4. Evaluate the performance of swarm intelligence algorithms
5. Apply swarm intelligent algorithms to robotic applications

Unit I: Introduction to swarm intelligence (6)

Basic philosophy, Need of swarm intelligence, Traditional approach vs. Swarm intelligence, Models of swarm behaviour, introduction to swarm intelligence methods: Particle swarm optimization, ant colony optimization, artificial bee colony, shuffled frog leaping algorithm, firefly algorithm etc. Applications of swarm intelligence to robotics systems

Unit II: Particle swarm optimization: (6)

Introduction, Mechanism of working of particle swarm optimization algorithm, parameter selection, convergence criteria, adaptive mechanisms, variants of PSO algorithm, hybridization, performance of algorithm - convergence rate and accuracy, termination criteria.

Unit III: Ant colony optimization: (6)

Introduction, Mechanism of working of amt colony optimization algorithm, collective intelligence, parameter selection, convergence, elitist ant system, Rank based ant systems, recursive ant colony optimization, Applications to combinatorial optimization problems.

Unit IV: Artificial bee colony optimization (6)

Artificial bee colony meta-heuristic: Initialization, employed bees, onlooker bees, scout bees, honey foraging behavior, Global Guided ABC Algorithm, Hybrid Guided Artificial Bee Colony (HGABC) Algorithm, hybridized artificial bee colony with simulated annealing, genetic algorithm etc.

Unit V: Other techniques based on swarm intelligence (6)

Shuffled frog leaping, Cat Swarm Optimization, Bat algorithm, glowworm swarm optimization, Fish school algorithm, firefly algorithm, Teaching-learning based optimization, Lion algorithm, civilized swarm optimization.

Unit VI: Applications of swarm intelligence in robotics: (6)

Swarm intelligence in following robotics applications: Robot path planning, Trajectory generation, inverse kinematics and dynamics, Robotic controller design, robot clustering, robot sorting, robot collaboration, Obstacle avoidance etc.

Reference Books:

1. Aboul Ella Hassanien, Eid Emary, 'Swarm Intelligence: Principles, Advances, and Applications', CRC Press, ISBN: 9781498741071
2. Pakize Erdogmus (Ed.) 'Particle Swarm Optimization with Applications', IntechOpen, ISBN: 9781789231489
3. Christian Blum, Daniel Merkle, Swarm Intelligence: Introduction and Applications, Springer, ISBN: 9783540740896
4. Pawar P. J., 'Evolutionary Computations for Manufacturing', Studium Press, 2019, ISBN: 978-93-85046-52-0

Robot Programming Lab

311508(B)

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Lectures: 02 hours / week	Practical: 01	PR: 25 Marks OR: 25 Marks

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Term Work

Term work will be based on following practical/design assignments

1. Programming using teach pendant method
2. Programming on VAL Language
3. Programming on RAPID Language
4. Programming on AML Language
5. Programming the robot for pick and place operation using any robot
6. Robot Programming for Color identification/shape identification/path tracking
7. Industrial visit and its report on industrial applications of robots

Artificial Intelligence for Robotics Lab

311509(B)

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Practical: 02 hours / week	Practical: 01	TW: 25 marks PR: 25 Marks

List of practical:

1. Programming in C or Matlab to implement fuzzy logic application for autonomous robot system.
2. Programming in C/ Matlab to implement simulated annealing/genetic algorithm for solving inverse kinematic problems
3. Programming in C/ Matlab to solve traveling salesman problem using ant colony optimization algorithm
4. Write program using Visual Prolog to create an expert system
5. Write program for obstacle avoidance in mobile robots using any one algorithm
6. Implement A* algorithm to Solve 8-puzzle problem using. Assume any initial configuration and define goal configuration clearly
7. Define the operators for controlling domestic robot; use these operators to plan an activity to be executed by the robot. For example, transferring two/three objects one over the other from one place to another. Use Means-Ends analysis with all the steps revealed.
8. Solving real time planning and scheduling problems using software like Witness/Pro-model

Flexible Manufacturing Systems Lab

311510(B)

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Practical: 02 hours / week	Practical: 01	TW- 25 Marks

Oral will be based on Assignment submitted on the topic and following practical work (Any 4)

1. Construction of model of cellular manufacturing system and performance evaluation using any software package.
2. Programming on CNC Lathe
3. Programming on CNC Milling
4. Robot programming for integrated process application
5. 3 D printing of a part
6. Programming for line/color follower AGV

Elective 2-Micro-electro Mechanical Systems Lab

311511(B)-I

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Practical: 02 hours / week	Practical: 01	OR - 25 Marks

List of Assignments: Oral will be based on the following assignments

1. MEMS system applications in robotics
2. Study of Micro fabrication Processes.
3. Case study of MEMS in magnetic actuators.
4. Study of Piezoelectric sensors and actuators from fabrication point of view.
5. Study of optical MEMS
6. Real life case study of MEMS.

Elective 2-Humanoid Robots Lab

311511(B)-II

Teaching Scheme	**Credit Scheme**	**Examination Scheme**
Practical: 02 hours / week	Practical: 01	OR - 25 Marks

1. Selection and design of sensors, actuators and other hardware in connection with humanoid robots
2. Forward Kinematics of Humanoid Robots
3. Inverse Kinematics of Humanoid Robots
4. Programing humanoid robots for bipedal gait generation and control, i.e. zero moment point (ZMP), central pattern generators (CPGs) and linear genetic programming (LGP).
5. Forward and inverse dynamics of Humanoid Robots
6. Programing humanoid robots with basic algorithms for computer vision.
7. Programing humanoid robots for dexterous manipulation for humanoid robots.

Elective 2-Modelling and Simulation Lab

311511(B)-III

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 02 hours / week	Practical: 01	OR - 25 Marks

List of Practical

1. Assignment on Principals of Simulation and Modeling.
2. Development of Mathematical model for Manufacturing processes/Machining.
3. Simulation of Material Handling system using software package.
4. Simulation of manufacturing system using software package
5. Introduction to programming language – SLAM
6. Introduction to programming language - SIMAN

Elective 2-Swarm Intelligence in Robotics Lab
311511(B)-IV

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 02 hours / week	Practical: 01	OR - 25 Marks

Programming in C/Python/Matlab for any 6 swarm intelligence methods for following applications in Robotics

1. Robot path planning and Trajectory generation
2. Inverse robot kinematics
3. Inverse robot dynamics
4. Robot controller design
5. Robot clustering and sorting
6. Obstacle avoidance
7. Robot vision system

Software Lab

311512

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 02 hours / week	Practical: 01	TW: 50 Marks

List of Practical

1. Solid modeling using any CAD software
2. Tool path generation and Part programming using any CAM software
3. Stress and deflection analysis using FEA software
4. Robot Kinematics and dynamics using software such as RoboAnalyser, Gazebo, Robologix etc.
5. Robot path planning using ROS/Matlab
6. Robot control system simulation using Matlab
7. Any one robot project application using Raspberry Pi

Internship

311513

Teaching Scheme	Credit Scheme	Examination Scheme
	Internship: 04	TW - 100 Marks

Course Outcomes:

On completion of the internship, learner will be able to –

1. To develop professional competence through industry internship.
2. To apply academic knowledge in a personal and professional environment
3. To build the professional network and expose students to future employees.
4. Apply professional and societal ethics in their day to day life.
5. To become a responsible professional having social, economic and administrative considerations.
6. To make own career goals and personal aspirations.

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 theoretical 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 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./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 [1].

Contacting various companies for Internship and 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. Student can take internship work in the form of Online/onsite work from any of the following but not limited to:

- Working for consultancy/ research project,
- Participation at Events (Technical / Business)/in innovation related completions like Hackathon,
- Contribution in Incubation/ Innovation/ Entrepreneurship Cell/ Institutional Innovation Council/ startups cells of institute /

- Learning at Departmental Lab/Tinkering Lab/ Institutional workshop,
- Development of new product/ Business Plan/ registration of start-up,
- Participation in IPR workshop/Leadership Talks/ Idea/ Design/ Innovation/ Business Completion/ Technical Expos,
- Industry / Government Organization Internship,
- Internship through Internshala,
- In-house product development, intercollegiate, inter department research internship under research lab/group, micro/small/medium enterprise/online internship,
- Research internship under professors, IISC, IIT's, Research organizations,
- NGOs or Social Internships, rural internship,
- Participate in open source development.

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

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 after every day by the supervisor/ in charge of the section where the student has been working.

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 Diary/workbook may be evaluated on the basis of the following criteria:

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

Internship Work Evaluation:

Every student is required to prepare a maintain documentary proofs of the activities done by him as internship diary or as workbook. The evaluation of these activities will be done by Programme 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 & Presentation Skills
- Team Work
- Creativity

- Planning & Organizational skills
- Adaptability
- Analytical Skills
- Attitude & Behavior at work
- Societal Understanding
- Ethics
- Regularity and punctuality
- Attendance record
- Log book
- 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. The student may contact Industrial Supervisor/ Faculty Mentor/TPO for assigning special topics and problems and should prepare the final report on the student's presence physically, if the student is found absent without prior intimation to the department/institute/concern authority/T & P Cell, entire training can be cancelled.

The report shall be presented covering following recommended fields but not limited to,

- Title/Cover Page • Internship completion certificate
- Internship Place Details- Company background-organization and activities/Scope and object of the study / personal observations
- 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 following recommended parameters

Technical knowledge, Discipline, Punctuality, Commitment, Willingness to do the work, Communication skill, individual work, Team work, Leadership…..

Audit Course 6:
Technical writing and communication skill
311514

This course is intended to equip the students with skills to write technical reports and also to equip them with skills to communicate and articulate in English (verbal as well as writing)

Technical Writing –

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion); Writing of abstracts, summaries, précis, citations etc.;
- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups; Editing and proof-reading; Writing of a review article.

Communication Skills –

- Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors);
- Concord;
- Collocation; Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech: Participation in group discussion: Facing an interview;
- presentation of scientific papers

Mandatory Audit Course 6:
Energy Auditing and Management in Industries
311094

Energy Auditing: Concepts, Need of Energy audit, Types of energy audit, Energy management (audit) approach, understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Energy audit instruments, Procedures and Techniques.

Energy Management: Design of Energy Management Programmes, Development of energy management systems, Importance, Industrial need of Energy Management, Preparation and presentation of energy audit reports, Monitoring and targeting, some case study and potential energy savings.

Reference Books:

1. Turner, W. C., Doty, S. and Truner, W. C., Energy Management Hand book, 7th edition, Fairmont Press, 2009.
2. De, B. K., Energy Management audit & Conservation, 2nd Edition, Vrinda Publication, 2010.
3. W.C. Turner, Energy Management Handbook, John Wiley and Sons.
4. L.C. Witte, P.S. Schmidt, D.R. Brown, Industrial Energy Management and Utilisation, Hemisphere Publication, Washington, 1988
5. Industrial Energy Conservation Manuals, MIT Press, Mass, 1982
6. Murphy, W. R., Energy Management, Elsevier, 2007.
7. Smith, C. B., Energy Management Principles, Pergamum, 2007
8. Handbook of Energy Audit, Sonal Desai, Mcgraw Hill Education Private Ltd.,