Savitribai Phule Pune University

Faculty of Science & Technology

Curriculum for

Fourth Year
Robotics & Automation

(2019 Course)

Savitribai Phule Pune University, Pune

Syllabus for

Fourth Year Robotics & Automation (2019 Course)

Semester- I

Course	Teaching Scheme (Hrs/week)			Examination Scheme						Credit	
	Theory	Practical/ Tutorial	PBL	Paper		TW	OR	PR	Total	TH	PR/OR
				Insem	Endsem						
SEM-I											
Machine Vision System	3			30	70				100	3	
Advanced Computational techniques	3			30	70				100	3	
Elective-I	3			30	70				100	3	
Elective-II	3			30	70				100	3	
Machine Vision System Lab		2					50		50		1
Advanced Computational techniques Lab		2						50	50		1
Elective-I Lab		2				25			25		1
Elective-II Lab		2				25			25		1
MOOCS						50			50		2
Project Stage-I		4				50	50		100		2
Total	**12**	**12**	**0**	**120**	**280**	**150**	**100**	**50**	**700**	**12**	**8**
								Total Credits			**20**

Abbreviations:

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

Semester- II

Course	Teaching Scheme (Hrs/week)			Examination Scheme					Credit	
	Theory	Practical/ Tutorial	PBL	Paper		TW	OR	PR	Total	TH/TW /TUT	PR/OR
				Insem	Endsem						
SEM-II											
Industrial Robotics & Material Handling Systems	3			30	70				100	3	
Field and Service Robotics	3			30	70				100	3	
Elective-III	3			30	70				100	3	
Elective-IV	3			30	70				100	3	
Industrial Robotics & Material Handling Systems Lab		2				25		50	75		1
Field and Service Robotics Lab		2				25	50		75		1
Project Stage-II			12			100	50		150		6
Total	**12**	**4**	**12**	**120**	**280**	**150**	**100**	**50**	**700**	**12**	**8**
									Total Credits	**20**	

Elective-I Subjects
Data Analytics
Modeling and Simulation
Intellectual Property Rights
Tool Design

Elective-II Subjects
Industry 4.0
Neural Networks and Fuzzy Systems
Process Planning and Cost Estimation
Maintenance and Safety Engineering

Elective-III Subjects
Mechatronics
Finite Element Analysis
Entrepreneurship Development
Product Design and Development

Elective-IV Subjects
Automobile Engineering
IOT and Machine Learning
Supply Chain Management
Reliability Engineering

Machine Vision System

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

Pre-requisites: Sensors Technology, Robot Programming, Artificial Intelligence for Robotics

Course outcomes:

Student will be able to:

1. Understand digital image using various algorithms with the help of computer programming.
2. Understand the role of image processing in different fields such as medical, engineering, space, biotechnology, ocean, agriculture, food industry, etc.
3. Realize the significance of digital image processing in automation.
4. Understand models for image degradation/restoration.
5. Know the mathematical calculations of basic filters used in digital image enhancement.

Unit I: Introduction to Vision System

Comparison with human visual system and perception level, digital image presentation, Definitions of digital image, Examples of the fields that use digital image processing, fundamental steps in image processing, components / elements of digital image processing systems, image acquisition, storage, processing, communication and display.

Unit II: Digital Image Fundamentals

Elements of visual perception – brightness adaption and discrimination, light and electromagnetic spectrum, image sensing and acquisition, sampling and quantization, some basic relationships between pixels, connectivity, adjacency, distance measures, different types of image sensors, different types of file formats.

Unit III: Image Enhancement in Spatial Domain:

point processing and mask processing, Basic gray level transformations, histogram processing, histogram equalization, histogram matching, local enhancement, histogram statistics, image subtraction, image averaging, basics of spatial filtering – smoothing, sharpening filters and order statistics filters.

Unit IV: Image Enhancement in Frequency domain

Introduction to Fourier Transform and frequency domain, The discrete Fourier Transforms – properties of 2-D Fourier Transform, smoothing frequency domain filters – ideal, butter worth, Gaussian low pass filters with additional examples of low pass filters, sharpening frequency domain filters – ideal, butter worth, Gaussian and Laplacian filters, unsharp masking, high boost filtering, homomorphic filtering, convolution and correlation, sampling, additional properties of 2-D Fourier transfer, Periodicity and need for padding

Unit IV: Image Restoration

Model for image degradation/restoration, noise models – probability density functions of noise, periodic noise and estimation of noise parameters; periodic noise reduction by frequency domain filtering, Arithmetic mean filters, geometric mean filters, adaptive filters, Band pass and band reject filters.

Unit VI: Image compression & Processing

Fundamentals of image compression and types of redundancy, error free and lossy compression, variable length coding – Huffman coding, arithmetic coding, LZW coding, run length coding.

Morphological Image Processing

Basic concept, Dilation and Erosion process for binary and gray image with applications, Opening & Closing for binary and gray image with applications, Hit-or-Miss Transformation, Basic Morphological Algorithms, textural segmentation.

References:

1. Refael C. Gonzalez and Richard E, Woods Digital Image Processing, Addison-WesleyISBN: 9780133356724
2. Refael C. Gonzalez and Richard E. Woods, Digital Image Processing Using MATLAB, Addison-Wesley, ISBN: 9780070702622
3. Scott E Umbaugh, Digital Image Processing and Analysis: Applications with MATLAB and CVIP tools , Taylor and Francis, ISBN: 1498766072
4. Scott EUmbaugh, Computer Vision and Image Processing Prentice-Hall International, ISBN: 9781439802052
5. A.K. Jain, Fundamentals of Digital Image Processing, Prentice-Hall of India, ISBN-100133361659
6. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing and Machine Vision, Cengage Learning, ISBN:9781133593607
7. Castleman K.R, Digital Image Processing, Prentice-Hall India, ISBN:0132114674

Advanced Computational techniques

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

Course outcomes:

Student will be able to:

1. Choose appropriate computational technique for solving issues in robotics and automation
2. Demonstrate understanding of computational techniques
3. Apply computational techniques for solving models in automation systems
4. Examine the performance of the computational techniques
5. Develop methodology to deal with issues in robotics and automation

Unit I: System of non-linear equations:

Fixed point iteration for a non-linear system, Newton Raphson method for solving system of non-linear equations, criteria for convergence, error analysis

Unit II: Fourier approximations:

Curve fitting with sinusoidal functions, Continuous Fourier series, Fourier integral and transforms, Discrete Fourier transforms, Fast Fourier transforms

Unit III: Boundary value and Eigen value problems:

Shooting method for solving boundary value problems, Finite difference approximation of boundary value problems, Polynomial method to determine Eigen values, power method, LR method and QR method.

Unit IV: Solution of partial differential equations-I:

Finite difference methods:
Parabolic: Forward time central space, Liebmann method, Crank Nicolson method,
Hyperbolic: Lax-Friedrichs method, Mac Cormack method
Others: Alternating direction-implicit, Finite-difference time-domain
Finite volume methods: Monotonic upstream-centered (MUSCL), Riemann Solver

Unit V: Solution of partial differential equations-II:

Finite element methods: hp-FEM, Discontinuous Galerkin (DG)
Meshfree Methods: Smoothed-particle hydrodynamics, Moving particle semi-implicit method

Unit VI: Advanced optimization techniques:

Sequential quadratic programming, Genetic algorithms, simulated annealing. Application to solve inverse kinematics problems.

References:

1. Smith G.D. “Numerical solutions for Differential Equations” Mc Graw Hill
2. Chapra S.C. and Canale R.P. “Numerical Methods for Engineers” Mc Graw Hill 2006.
3. Ketter and Prawel “Modern Methods for Engineering Computations” Mc Graw Hill
4. Rajasekharan S. “Numerical Methods for Initial and Boundary value problems,” Khanna publishers 2003.
5. S.S. Rao , Optimisation Theory and applications , ,Wiley Eastern.

Elective I: Data Analytics

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, Numerical Techniques and Optimization Methods

Course objectives:
The objective is to provide a basic understanding of data analysis using statistics and to use of computational tools onproblems of applied nature.

Outcomes:
After learning this subject, the student will be able to:
1. Effectively visualize and interpret the data
2. Apply predictive and prescriptive techniques for production engineering applications
3. Use data analysis for engineering applications through the powerful tools of data application

Unit I: Introduction to data analytics
Significance & applications of data analytics, Data collection, data processing, data transformation, data integration, data visualization, basic statistics, inferential statistics

Unit II: Descriptive analytics
Uni-variate/multi-variate statistics, bi-variate associations, correlations, covariance, analysis of variance (ANOVA)

Unit III: Predictive analytics
Multiple regression, conjoint analysis, neural networks, data clustering, Data mining

Unit IV: Classification techniques
Linear classifiers, Quadratic classifiers, Support vector machines, Random forests.

Unit V: Prescriptive analytics
Decision tree analysis, Expert system, principal component analysis, genetic algorithms

Unit VI: Reinforcement learning
Markov chain analysis, Monte Carlo simulation, Q learning, State action reward state action (SARSA) learning

Books:

1. Acharya Seema and Chellappan, Big Data and Analytics, Willey India Pvt. Ltd. (2015), ISBN: 9788126554782
2. Data Science and Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data, EMC Education Services, Willey India Pvt. Ltd. (2016), ISBN: 978-1-118-87622-0
3. Michael Minelli, Michale Chambers, Ambiga Dhiraj, Big Data Analytics: Emerging Business Intelligence and analytics trends for today‘s business, Willey India Pvt. Ltd. (2015)
4. Bharti Motwarni Data Analytics with R, 2019, Wiley, ISBN: 9788126576463
5. Bhattacherjee Vandana, Bishnu Partha Sarathi, Data Analysis : Using Statistics And Probability With R Language, Phi Learning, ISBN: 9789387472655

Elective I: Modelling and Simulation

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

Pre-requisites: Machine Drawing, Engineering Mathematics III

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
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
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
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
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
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

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

Text Books:

1. Averill M Law, "Simulation Modeling and Analysis", Fourth Edition, Tata McGraw Hill Education Private Ltd, New Delhi, 2010.
2. Banks, J., J. S. Carson II, and B. L. Nelson. "Discrete-Event System Simulation", Second Edition, Prentice Hall, Upper Saddle River, New Jersey, 1996
3. Fishman, G.S., "Monte Carlo: Concepts, Algorithms and Applications", Chapman & Hall, New York, 2006.

Elective-I: Intellectual Property Rights

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

Course outcomes

1. Apply adequate knowledge on patent and copyright for their innovative research works
2. Carry out prior art for a given case
3. Gain useful insight on novelty of their idea from state-of-the art search. This provide further way for developing their idea or innovations
4. Create opportunities and catch up Intellectual Property(IP) as an career option in R&D IP Counsel and government Jobs –Patent Examiner
5. Create opportunities and catch up Intellectual Property(IP) as an career option in Private Jobs, Patent agent and Trademark agent
6. Create opportunities in consulting in IPRs

UNIT I: Overview of Intellectual Property

Introduction and the need for intellectual property right (IPR), Kinds of Intellectual Property Rights: Patent, Copyright, Trade Mark, Design, Geographical Indication, Plant Varieties and Layout Design, Genetic Resources and Traditional Knowledge, Trade Secret -IPR in India : Genesis and development, IPR in abroad, Major International Instruments concerning Intellectual Property Rights: Paris Convention, 1883, the Berne Convention, 1886, the Universal Copyright Convention, 1952, the WIPO Convention, 1967,the Patent Co-operation Treaty, 1970, the TRIPS Agreement, 1994

UNIT II: Patents

Patents -Elements of Patentability: Novelty , Non Obviousness (Inventive Steps), Industrial Application -Non - Patentable Subject Matter, Registration Procedure, Rights and Duties of Patentee, Assignment and licence , Restoration of lapsed Patents, Surrender and Revocation of Patents, Infringement, Remedies & Penalties - Patent office and Appellate Board

UNIT III: Copyrights

Nature of Copyright -Subject matter of copyright: original literary, dramatic, musical, artistic works; cinematograph films and sound recordings, Registration Procedure, Term of protection, Ownership of copyright, Assignment and license of copyright -Infringement, Remedies & Penalties –Related Rights -Distinction between related rights and copyrights

UNIT IV: Trademarks

Concept of Trademarks -Different kinds of marks (brand names, logos, signatures, symbols, well known marks, certification marks and service marks) -Non Registrable Trademarks -Registration of Trademarks -Rights of holder and assignment and licensing of marks -Infringement, Remedies & Penalties -Trademarks registry and appellate board

UNIT V: Other forms of IP

Design: meaning and concept of novel and original -Procedure for registration, effect of registration and term of protection

Geographical indication: meaning, and difference between GI and trademarks -Procedure for registration, effect of registration and term of protection

Plant variety protection: meaning and benefit sharing and farmers' rights –Procedure for registration, effect of registration and term of protection

Layout Design protection: meaning –Procedure for registration, effect of registration and term of protection

UNIT VI: Current Contour

India`s New National IP Policy,2016 –Govt. of India step towards promoting IPR –Govt. Schemes in IPR –Career Opportunities in IP -IPR in current scenario with case studies

Reference book:

1. Ahuja, V K. Law relating to Intellectual Property Rights. India, IN: Lexis Nexis. 2017.
2. Neeraj Pandey, Khushdeep Dharni, I Ntellectual Property Rights, Phi Learning Pvt. Ltd., 2014.
3. David Pressman, Blau, Patent It Yourself: Your Step-by-Step Guide to Filing at the U.S. Patent Office, ISBN: 978-1-4133-2539-3, 2018.
4. Rachna Singh Puri, Arvind Viswanathan, Practical Approach to Intellectual Property Rights, I. K. International Pvt Ltd, ISBN: 978-93-80026-69-5, 2009

Elective I: Tool Design

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

Prerequisites: Engineering Graphics, Manufacturing technology

Course Outcomes:

Students will be able to-

1. Describe press working operations
2. Apply knowledge to design and construct blanking and progressive die
3. Apply knowledge to design and construct drawing and bending die
4. Understand forging operation and apply knowledge to design and construct forging die
5. Describe injection moulding operation and apply knowledge to design and construct injection mould
6. Apply knowledge to design and construct die casting die

Unit I: Introduction of Press working

Press working terminology, Basic operations, types of presses- mechanical, hydraulic, pneumatic and their mechanisms, elements of die sets, types of die sets, types of dies: simple, compound, progressive, combination and inverted dies, types of punches, Methods of reduction of shear force, types of strip layouts, types of strippers, types of pilots, types of stoppers, selection of dowel pins and screws.

Unit II: Design of Press tool dies

Design of Blanking and Progressive dies

Strip layout, percent utilization, Calculation of force, Press capacity, clearances, die and punch size, center of pressure, methods of piloting, Design of Blanking dies, Design and drawing of progressive, compound and combination die.

Design of Drawing and Bending Dies

Design of shallow and deep drawing die, Calculation of blank size by area and graphical method and standard formula, percentage reduction in each stage , number of draws, drawing force, blank holding force, press capacity, ironing force.

Types of Bending dies, Developed length calculation, bending force, spring back

Unit III: Design of Forging Dies

Multi Impression Die: Design of forging die for multi-impression die-: selection of parting line, drafts, fillet & comer radii, ribs and webs, stock size calculation, flash and gutter, design of fullering, edging, blocking, finishing impressions, trimming dies, Die block dimensions, die inserts.

Upsetting die: Rules for upset forging, design of upsetdie.

Unit IV: Design of Injection mould

Integer mold, insert mold, bolster, guide pillar, register ring, types of nozzles splits, side cores & side cavities, molding internal undercuts, types of ejectors, types of runners & gates. Determination of number of cavities, design of feed system- design of sprue, sprue puller, runners & gates, types of cooling system, design of cooling channels, heat transfer considerations, determination of mould opening force & ejection force, design of ejector system, use of CAD for mould design.

Unit V: Die Casting Die Design

Introduction to die casting, die casting machines: hot & cold chamber, metals for die casting, product design, types of die castings dies: mechanical die design, die set up techniques, die locking methods, interlocks & safety devices, specific details of die constructions, casting ejection, cores, slides, loose die pieces, types of cores, directional solidification, types of feeders, die venting, water cooling, classification of dies- single, combination, multi-impression, general details of die design, inserted impressions, concepts of cavity fill, metal feed system, die casting defects & their remedies, die and plunger lubrication

Unit VI: Automation in Tool Design

Computer-aided sequence planning of shearing operations in progressive dies, feature extraction and manufacturability assessment of sheet metal parts, computer-aided strip layout design for sheet metal progressive dies, design optimization of spring back in a bending and deep drawing process, computer aided forging die design, computer-aided mould design, gating system design optimization for injection moulding, material flow analysis.

References:

1. Donaldson, Lecain and Goold, “Tool Design”, Tata McGraw Hill, ISBN 0 07 0992746.
2. J R Paquin, “Die design Fundamentals”, Industrial Press Inc., ISBN 0 8311 11720.
3. Doehler H.H, ”Die Casting”, Mc GrawHill
4. P.N. Rao, “Manufacturing Technology, Foundry, Forming and Welding ”, Tata McGraw Hill, ISBN 0 07 4518631.
5. R.G. W. Pye, “Injection Mould Design(Design manual for plastic industry)”,EWP
6. P.H. Joshi, “Press Tools Design & Construction”, Wheeler Pub., ISBN 8185814465.
7. P. C. Sharma, “Production Engineering”, S. Chand, ISBN 81 219 04218.
8. Dr. Surender Kumar, “Production Engg. Design” (Tool Design), SatyaPrakashan
9. A.S. Athalye, “Plastics Materials handbook”, Multitech Pub. Co., ISBN
10. Bill Andresen, Die Casting Engineering: A Hydraulic, Thermal, and Mechanical Process, Marcel Dekker, New York, ISBN: 0-8247-5935-4

Elective II: INDUSTRY 4.0

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

Pre-requisites: Sensors Technology

Course Outcomes:

1. Student will be able to:
2. 1. Remember the challenges for Industry 4.0
3. 2. Understand opportunities and challenges of Industry 4.0
4. 3. Understand strategies for competing in an Industry 4.0 world
5. 4. Use various Industry 4.0 technologies.
6. 5. Apply Internet of Things (IoT) in industries to modify the various existing industrial systems

Unit I: Introduction to Industry 4.0

Introduction: Sensing & actuation, The Various Industrial Revolutions. Digitalization and the Networked Economy. Drivers, Enablers, Compelling Forces and Challenges for Industry 4.0. The Journey so far: Developments in India, USA, Europe, China and other countries. Comparison of Industry 4.0 Factory and Today's Factory. Trends of Industrial Big Data and Predictive Analytics for Smart Business Transformation

Unit II: Internet of Things (IoT) and smart systems

Internet of Things (IoT) & Industrial Internet of Things (IIoT) & Internet of Services, Smart Manufacturing, Smart Devices and Products, Smart Logistics, Smart Cities, Predictive Analytics

Unit III: System, Technologies for enabling Industry 4.0

Cyber physical Systems, Robotic Automation and Collaborative Robots, Support System for Industry 4.0, Mobile Computing, Related Disciplines, Cyber Security.

Unit IV: Role of data, information, knowledge and collaboration in future organizations

Resource-based view of a firm, Data as a new resource for organizations, Harnessing and sharing knowledge in organizations, Cloud Computing Basics, Cloud Computing and Industry 4.0.

Unit V: Applications and Case Studies

Artificial Intelligence, Industry practices in AI, Industry 4.0 laboratories, IIoT case studies, Case studies from HKPolyU students

Unit VI: Business issues in Industry 4.0

Opportunities and Challenges, Future of Works and Skills for Workers in the Industry 4.0 Era, Strategies for competing in an Industry 4.0 world

References:

1. “Industry 4.0: The Industrial Internet of Things”, by Alasdair Gilchrist (A press), ISBN 978-1-4842-2046-7.
2. “Industrial Internet of Things: Cyber manufacturing Systems” by Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat (Springer).

Elective II: Neural Networks and Fuzzy systems

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

Pre-requisites: Set Theory

Course Outcomes:
After learning the course the students should be able to:
1. Identify and describe Fuzzy Inference Systems and their roles in building intelligent machines
2. Recognize the feasibility of applying Neural Networks and Fuzzy systems for a particular problem
3. Apply fuzzy logic and reasoning to handle uncertainty and solve engineering problems
4. Apply neural networks to pattern classification and regression problems
5. Effectively use existing software tools to solve real problems using Neural Networks and Fuzzy systems
6. Evaluate and compare solutions by Neural Networks and Fuzzy systems for given problems.

Unit I :Neural Networks: Introduction
Humans and Computers, Organization of the Brain, Biological Neuron, Biological and Artificial Neuron Models, Hodgkin-Huxley Neuron Model, Integrate-and-Fire Neuron Model, Spiking Neuron Model, Characteristics of ANN, McCulloch-Pitts Model, Historical Developments, Potential Applications of ANN.
Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions,

Unit II: Essentials of Artificial Neural Networks
Artificial Neuron Model, Operations of Artificial Neuron, Types of Neuron Activation Function, ANN Architectures, Classification Taxonomy of ANN – Connectivity, Neural Dynamics (Activation and Synaptic), Learning Strategy (Supervised, Unsupervised, Reinforcement), Learning Rules, Types of Application

Unit III: Neural Networks Architecture
Single layer and multilayer feed forward networks, recurrent networks. Various learning techniques; perception and convergence rule, Auto-associative and hetro-associative memory**,** perceptron model, solution, single layer artificial neural network, multilayer perception model; back propagation learning methods, effect of learning rule co-efficient ;back propagation algorithm, factors affecting back propagation training, applications

Unit IV :Fuzzy Logic: Introduction
Basic concepts of fuzzy logic, Fuzzy sets and Crisp sets, Fuzzy set theory and operations, Properties of fuzzy sets, Fuzzy and Crisp relations, Fuzzy to Crisp conversion

Unit V: Fuzzy Logic: Fuzzy Membership, Rules
Membership functions, interference in fuzzy logic, fuzzy if-then rules, Fuzzy implications and Fuzzy algorithms, Fuzzyfications & Defuzzificataions, Fuzzy Controller, Industrial applications.

Unit VI: Fuzzy Logic Applications
Operations of Fuzzy relation, Defuzzification, Fuzzy rule base and approximate reasoning, Fuzzy Inference Systems, Design a fuzzy logic controller: Mamdani and Sugeno Architecture

Text Books:

1. S. Rajsekaran & G.A. Vijayalakshmi Pai, “Neural Networks,Fuzzy Logic and Genetic Algorithm:Synthesis and Applications” Prentice Hall of India.
2. N.P.Padhy,”Artificial Intelligence and Intelligent Systems” Oxford University Press.

Reference Books:

1. Siman Haykin,”Neural Netowrks”Prentice Hall of India
2. Timothy J. Ross, “Fuzzy Logic with Engineering Applications” Wiley India.
3. Kumar Satish, “Neural Networks” Tata Mc Graw Hill
4. Neural Networks and Fuzzy Logic System by Bart Kosko, PHI Publications.

Elective II: Process Planning and Cost Estimation

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 03 hours / week	Theory: 03	In-Sem: 50 Marks End-Sem: 50 Marks

Pre-requisites: None

Course outcomes: Students should be able to:

1. Understand the role of Process planning in cost estimation
2. Understand the concept of CAPP
3. Estimate the cost
4. Apply cost estimation concept.

Unit I: Process Planning

Introduction- Process & Production Planning, Process Planning & Concurrent Engineering,Types of production, standardization- Production design & selection.

Unit II: Design and Concepts Of Process Plan

Selection of processes, tools, cutting parameters & machine tools- Jigs and Fixtures - Grouping of processes- Sequencing of operations- Selecting primary manufacturing processes for rough & refined needs Process capability, Process Charts.

Unit III: Manual and Computer Aided Process Planning

Retrieval type/variant approach, group technology, generative approach, logics decision tress and tables, axiomatic approach, AI expert systems, feature recognition, applications.

Unit IV: Estimating and Costing

Concepts, differences, different costing methods, classification of costs, cost grid-problems.
Labour cost: direct, indirect estimation labour norms: time study rating labour cost variances; material cost direct, indirect estimation material issue valuation material cost variances problems. Overhead cost Elements factory, administrative, sales and distribution expenses methods of absorbing overheads direct labour, direct Material, Machine Hour Rate methods depreciation methods accounting for service department expenses problems.

Unit V: Cost Calculations

Machined components, welded components, forged components, powder metallurgy parts, calculation of sales cost, case studies, use of computers in cost estimation, cost of rejection. Optimum Machining Conditions: Taylor‘s equation, deriving the equation for optimum economic cutting velocity– selection of cutting speed for optimum cost, problems process capability analysis.

Unit VI: Break Even Analysis

Concept, make or buy decision, assumptions, merits and demerits of break even analysis. Applications: Linear, multi product break-even analysis.
Learning curves, product life cycle cost analysis -Tools and techniques–activity based costing - concepts, cost drivers; introduction to target costing - need and applications.

References:

1. Kannappan D, Mechanical Estimating and Costin, Tata McGraw Hill, New Delhi, 2003.
2. Kesavon R and others, Process Planning and Cost Estimation, New Age International, Chennai, 2005.
3. Thomas E. Vollmann et al., Manufacturing Planning and Control Systems, Galgotia Publications, Delhi, 1998.
4. Samuel Eilon, Elements of Production Planning and Control, MacMillan, London, 1985.
5. ASME, Manufacturing Planning and Estimation-Hand Book, McGraw Hill, New Delhi, 1963.
6. Frederic C Jelen and James H Black, Cost and Optimization Engineering, McGraw Hill, New Delhi, 1983.

Elective II: Maintenance and Safety Engineering

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

Pre-requisites: Industrial Engineering and Management

Course outcomes:

Student will be able to:

1. Understand the breakdown maintenance & preventive maintenance
2. Implement the TPM in the organization.
3. Analyze the safety system & hazards.
4. Categorize fire protection system
5. Understand the provisions in factory act for safety.

Unit I: Maintenance

Introduction**,** Types – breakdown, preventive, predictive, TPM; elements of preventive maintenance – checklist, schedule, procedure.

Unit II: Total Productive Maintenance

Principles; preparatory stages of implementation – TPM organisation structure, creation; basic TPM policies and aids, master plan.

TPM Implementation**:** Small group activities, autonomous maintenance, establishing planned maintenance, training, developing equipment management program.

Unit III: Safety Systems Analysis

Definitions, safety systems; safety information system: basic concept, safety cost / benefit analysis; industrial safety engineering, OSHA regulations.

Hazard analysis**:** General hazard analysis: electrical, physical and chemical hazard, detailed hazard analysis. Cost effectiveness in hazard elimination.

Unit IV: Fire Protection System

Chemistry of fire, water sprinkler, fire hydrant, alarm and detection system. Suppression system: CO_2 system, foam system, Dry Chemical Powder (DCP) system, halon system, portable extinguisher.

Unit V: Safety In Machine Operation

Design for safety, lock out system, work permit system, safety in use of power press, cranes. Safety in foundry, forging, welding, hot working and cold working, electroplating and boiler operation.

Unit VI: Robot Safety And Law

Risk assessment, Safeguarding devices, Awareness devices Provisions in factory act for safety, explosive act, workmen compensation act, compensation calculation. Pollution control act.

Text Books:

1. John Ridley, Safety at Work, Butter Worth Publisher, Oxford.
2. Robinson C J and Ginder A P, Implementing TPM", Productivity Press, USA,

References:

1. Dhillon B S, Maintainability, Maintenance and Reliability for Engineers, CRC Press, 2006.
2. Heinrich H W, Industrial Accident Prevention, National Safety Council, Chicago
3. "Personal Protective Equipment", National Safety Council, Bombay.
4. Accident Prevention Manual for Industrial Operations, National Safety Council, Chicago

Machine Vision Lab

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

Practical Sessions:

1) Learning and implementing basic MATLAB commands.
2) Forming script file and function file in MATLAB.
3) Understanding different image classes.
4) Use of arithmetic and logical operators on images.
5) Image segmentation.
6) Blurring the given image by spatial convolution method.
7) Blurring and sharpening of image with built in command and performing scaling of the image
8) Performing negative, log, power-law and contrast stretching transformations on given image
9) Matching of the histogram of image with the specified one.
10) Implementing 1-D and 2-D Discrete Fourier Transformation of given image.

Advanced Computational techniques Lab.

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

Implement C/ Matlab program for the following toany case study related to robotics and automation:

1. Newton Raphson method for solving system of non-linear equations
2. Fast Fourier transforms for curve fitting
3. Shooting method for solving boundary value problems
4. Solution of partial differential equations using finite difference method
5. Solution of partial differential equations using finite element method
6. Solution of constraint optimization problem using genetic algorithm/simulated annealing

Elective-I: Data Analytics Lab

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

List of practical

1. Introduction to statistical learning and R-Programming
2. Practice and analysis with R
3. Case study on data management using Hadoop
4. Predictive analytics project using Matlab
5. Case study on scalable computations using MapReduce
6. Case study on predictive/prescriptive analysis using Minitab

Elective-I: Modelling and Simulation Lab

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 02hours / 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
6. Practical case study on application of Monte Carlo simulation in queue systems, inventory models.
7. Development of mathematical model for machining processes using software package .
8. Kinematic and dynamic analysis of mechanisms using mechanism analysis software

Elective-I: Intellectual Property Rights Lab

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

Term Work

Term work will be based on following practical/design assignments

1. Report on the procedures for Intellectual Property.
2. Prior art for any product.
3. Report on the procedures for patents
4. Report on the procedures for copyrights
5. Report on the procedures for trademark
6. Report on Design, Geographical indication, Plant variety protection, Layout Design protection intellectual property.
7. Report on National IP Policy and current scenario.

Elective I: Tool Design Lab

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

Term Work (Any four of the following: All drawings on A2 size drawing sheet)

1. Design and drawing of Blanking die.
2. Design and drawing of Progressive die.
3. Design and drawing of Drawing die.
4. Design and drawing of Forging die.
5. Design and drawing of single cavity injection mould.

Elective-II: Industry 4.0 Lab

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 02 hours / week	Practical: 01	Term Work - 50 Marks

The term work will be based on following assignments / practical's

1. Industrial Internet of Things (IIoT) for industry 4.0
2. Components of industry 4.0
3. Cloud Computing and Industry 4.0.
4. Artificial intelligence for Industry 4.0.
5. Case study of industry 4.0/ Industrial Internet of Things (IIoT)
6. Industrial Visit

Elective-II: Neural Network and Fuzzy system Lab

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

Term Work:

List of Practicals:

In this students should identify an application area, state the problem, apply fuzzy logic and/or artificial neural networks to solve the problem, present the result, and write a report.

1. Applications of neural network in robot navigation
2. Application of fuzzy logic in control and automation
3. Trajectory prediction using neural networks
4. Fuzzy based robot navigation
5. Noise cancellation using neural

Major Equipments / softwares:

Students may implement open ended problems on some Microprocessors / DSP boards. Computers with MATLAB / Scilab software may serve the purpose

List of Open Source Software/learning website:

The website of NPTL may be utilized for additional learning.

Open Source Software: Scilab or C Other Software(s) MATLAB® (if license available)

Elective-II: Process Planning and Cost Estimation Lab

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

Term work will be based on the following practical:

1. Process sheet design of one component for mass production.
2. Time estimation for assembly using flow-charting techniques.
3. Labour costing using Time Study concept.
4. Manufacturing Cost calculations for the component selected for process sheet design.
5. A Case study on Activity Based Costing.

Process sheet design shall include detailed analysis of part print, planning the best sequence of machining operations, selection of proper equipment and tooling, Selection of datum surfaces, stock preparation and blank size selection, machining time calculations, time estimates and standards, design of jigs & fixtures, design of special tooling such as form tool if required, suggest appropriate inspection methodology, preparation of process picture sheets and operation route sheet etc.

Elective-II: Maintenance and safety Engineering Lab

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

The term work shall consist of any six assignments based on the following topics.

1. To perform preventive maintenance – checklist & schedule of pick & place robot.
2. To perform risk assessment for robot.
3. To calculate safe distance of operational robot.
4. To study the safety locking switch in robot.
5. To study self monitoring hydraulic double valve.
6. To demonstration fire protection system.
7. Assignment on safety standards for industrial robot.

Project Phase-I

Teaching Scheme	Credit Scheme	Examination Scheme
Lectures: 04 hours / week	Pr/Or: 02	Termwork: 50 Marks

Pre-requisite:
1. Students are required to undergo 3 to 4 weeks industrial training / implant training /in-house project based learning/project related skill development course/ industrial survey report before commencement of first semester of Final year .
2. Submit detailed report of 25-30 pages of the same.
3. Project registration will be based on completion of above activities.

The student shall take up a suitable project, the scope of the project shall be such as to complete it within the time schedule, the term work shall consist of:

A detailed report to be prepared based on any one of the following topics

i. Manufacturing / Fabrication of a prototype of Robotic / Automated system including selection, concept, design, material, manufacturing the components, assembly of components, testing and performance evaluation.

ii. Improvement of existing Robotic / Automated system.

iii. Design and fabrication of end effectors for robot

iv. Computer aided design, analysis *of* components such as stress analysis.

v. Modeling and Simulation of Robotic and Automation systems

vi. Robot Kinematics and Dynamic analysis

vii. Low cost automation, Computer Aided Automation in Manufacturing.

viii. Ergonomics and safety aspects of robotic systems

ix. Management Information System.

x. Product design and development

xi. Jigs and Fixtures, dies, tools, special purpose equipment, inspection gauges, measuring instruments for machine tools.

xii. Problems related to Productivity improvements / Value Engineering / Automated Material Handling Systems

Two copies of project Report shall be submitted to the college. **The students shall present and submit their Project Phase-I report to the internal and external examiner from college/Industry.**

Industrial Robotics and Material handling Systems

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

1. Understand about material handling system
2. Understand storage and data capturing system
3. Describe the basic concepts, parts of robots and types of robots.
4. Select the robots according to its usage.
5. Describe various applications of robots, justification and implementation of robot.

Unit I: Introduction to Material handling

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

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

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

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

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

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

References Books

1. Groover M. P., “Automation, Production Sysytems, and Computer –Integrated Manufacturing”,Pearson
2. Education,ISBN-81-7808-511-9
3. Deb S.R., “Robotics”, Tata McGraw Hill Publications, New Delhi. ISBN 13: 9780070077911
4. Yoram Koren, & quot; Robotics for Engineers", McGraw Hill Book Co. ISBN-10: 0070353999, ISBN-13: 978-0070353992
5. Groover M.P., Weiss M., Nagel R.N., Odrey N.G., "Industrial Robotics Technology - Programming and Applications & quot;, McGraw Hill Book Co. ISBN-10: 1259006212, ISBN-13: 978-1259006210
6. Fu K.S., Gonzalex R.C., Lee C.S.G., "Robotics Control Sensing, Vision and intelligence", McGraw Hill Book Co. ISBN 10: 0070226253 / ISBN 13: 9780070226258
7. Hall A.S., & quot; Kinematics and Linkage Design", Prentice Hall. ISBN-10: 0881332720, ISBN-13: 978- 0881332728
8. Todd D.J., “Fundamentals of Robot Technology”, Wiley Publications, ISBN:978-0-470-20301-9

Field and Service Robotics

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

Pre-requisites: Sensor technology, Artificial Intelligence for robotics, robot programming

Course outcomes:

Student will be able to:

1. Understand the examples and Specifications of service and field Robots
2. Understand the robot kinematics.
3. Analyze the localization.
4. Perform the planning & navigation.
5. Understand the humanoid in robotics.

Unit I: Introduction

History of service robotics – Present status and future trends – Need for service robots - applications- examples and Specifications of service and field Robots. Non conventional Industrial robots.

Unit II: Robot Kinematics

Kinematic Models and Constraints – Maneuverability – Workspace – Control.

Unit III: Localization:

Introduction - Bayes filter – Kalman Filter - Extended Kalman Filter - Information Filter - Histogram Filter - Particle Filter – Challenges of Localization- Map Representation- Probabilistic Map based Localization-Monte carlo localization- Landmark based navigation-Globally unique localization- Positioning beacon systems- Route based localization – Mapping - Metrical maps - Grid maps - Sector maps – Hybrid Maps.

Unit IV: Mapping

Mapping - Metrical maps - Grid maps - Sector maps – Hybrid Maps

Unit V: Planning and Navigation

Introduction-Path planning overview- Global path planning – A* Algorithm - local path planning - Road map path planning- Cell decomposition path planning-Potential field path planning-Obstacle avoidance – Path control.

Unit VI: Humanoids

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

References:

1. Roland Siegwart, Illah Reza Nourbakhsh, DavideScaramuzza,‖Introduction to Autonomous Mobile Robots‖, Bradford Company Scituate, USA, 2011.
2. RiadhSiaer, The future of Humanoid Robots- Research and applications‖,Intech Publications, 2012.
3. Sebastian Thrun, Wolfram Burgard, Dieter Fox, ProbabilisticRobotics‖, MIT Press, 2005.
4. Howie Choset, Kevin LynchSeth Hutchinson, George Kantor, Wolfram Burgard,
5. Lydia Kavraki, and Sebastian Thrun, ―Principles of Robot Motion-Theory, Algorithms, and Implementation, MIT Press, Cambridge, 2005.
6. Bruno Siciliano, Oussama Khatib, Springer Hand book of Robotics, Springer, 2014.

Elective – III Mechatronics

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**,** Basic Electrical Engineering, Basic electronics Engineering

Outcomes:

After learning this subject, the student will:

1. Understand the control system basics and the types of control systems
2. Apply knowledge of response specifications of control system.
3. Use controller principles for composite modes of control
4. Be Able to do PLC programming, programming with counters and timers, real time PLC programming examples.
5. Apply the Mechatronics system, actuators, sensors and transducers used digital signal processing in real life problems

UNIT I: Sensors and Transducers

Introduction to Mechatronics, Open and Closed loop control system, Block Diagram Algebra With respect to Types, Range, and Applications and limitations, Thermocouples, Thermistors and Resistance Temperature Detectors With respect to Construction, Working and Applications, Linear Variable Differential Transducer. With respect to Principle, Types, and Applications, Strain Gauges, Gauge Factor and Measurement of Strain With respect to construction, working and specifications Electromagnetic Flow meter. With respect to specifications and applications, Capacitive and Inductive Proximity sensors Angular Velocity measurement, Tacho generators, Rotary Encoders

UNITII: Analog Signal Conditioning

Passive Circuits, Voltage dividers, Wheatstone‘s bridge, Low pass, high pass and bandpass filters. Op-Amps, Characteristics and Specifications, Voltage Follower, Inverting Amplifier, Non Inverting Amplifier, Summing Amplifier, Instrumentation Amplifier, Integrator, Differentiator. Current To Voltage Converter, Current to Voltage Converter Numerical Examples based on Wheatstone‘s Bridge and Op-Amps

UNIT III: Interfacing

Logical Gates, Boolean Algebra, Binary, Octal and Hexadecimal Number Systems and their significance. Analog to Digital Conversion SAR & R-2R Digital to Analog Conversion Sample and Hold Circuits, Sampling Theorem, Samplifing Frequency, Quantization. Numerical Examples based on ADC, DAC and Sampling

UNIT IV: Modelling and Analysis

Process Control Basics, Control System Parameters Process Dynamics Laplace Transform Basics, Dead Time Responses in Laplace Form Lag Responses in Laplace Form, Types of Second-Order Responses Faculty of Engineering Savitribai Phule Pune University, Pune B. E. [Production Engineering] Syllabi 2015 Course

UNIT V: Control System

Controller Actions, Proportional Controllers (P Mode), Integral Controllers (I Mode) with examples of plotting controller action vs time for respective error time plot Proportional-Integral Controllers (PI Mode) with examples Derivative Controllers (D Mode) Proportional-Derivative Controllers (PD Mode) with examples Proportional-Integral-Derivative Controllers (PID Mode) with examples

UNIT VI: PLC Programming

Introduction to PLC Programming, Types of PLC Languages, Ladder Diagram Format, Ladder Relay Instructions, Ladder Relay Programming, Timer Instructions with example Counter Instructions with example

Reference Book

1. C D Johson, Process Control Instrumentation Technology, 7th Edition, Prentice Hall of India Pvt Ltd. 2005.
2. L. A. Bryan, E. A. Bryan, Programmable Controllers : Theory and Applications, Industrial Text Company Publications, 3/e, 2016.
3. Alciatore & Histand, Introduction to Mechatronics and Measurement system, 4th Edition, Mc-Graw Hill publication, 2011. 2. Bishop (Editor), Mechatronics – An Introduction, CRC Press, 2006

Elective III: Finite Element Analysis

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

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

Course Outcomes

Students will be 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

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

Introduction to different approaches used in FEA such as direct approach, Variationalapproach,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

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: Axi-symmetric solids subjected to axi-symmetric loading

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

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

Unit VI: Dynamic analysis

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).

Text Books

1. A First Course in the Finite Element Method, Daryl L. Logan
2. Concepts and Applications of Finite Element Analysis, R. D. Cook, et al. Wiley, India

Reference Books

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

Elective III: Entrepreneurship

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

Pre-requisites: Production Management, Industrial Engineering and Quality Assurance

Course Outcomes: After Successful completion of this course students will be able to:

1. Appreciate the importance of embarking on self-employment and has developed the confidence and personal skills for the same.
2. Start a small business enterprise by liaising with different stake holders
3. Effectively manage small business enterprise.
4. Identify projects of current age
5. Incorporate partnership laws, business ownership

Unit I: Entrepreneurship

Definition. growth of small scale industries in developing countries and their positions vis-a-vis large industries; role of small scale industries in the national economy; characteristics and types of small scale industries; demand based and resources based ancillaries and sub-control types. Government policy for small scale industry; stages in starting a small scale industry.

Unit II: Motivation

Major Motives Influencing an Entrepreneur – Achievement Motivation Training, Self Rating, Business Games, Thematic Apperception Test – Stress Management, Entrepreneurship Development Programs – Need, Objectives.

Unit III: Project identification

Assessment of viability, formulation, evaluation, financing, field-study and collection of information, preparation of project report, demand analysis, material balance and output methods, benefit cost analysis, discounted cash flow, internal rate of return and net present value methods.

Unit IV: Accountancy

Preparation of balance sheets and assessment of economic viability, decision making, expected costs, planning and production control, quality control, marketing, industrial relations, sales and purchases, advertisement, wages and incentive, inventory control, preparation of financial reports, accounts and stores studies.

Unit V: Project Planning and control

The financial functions cost of capital approach in project planning and control. Economic evaluation, risk analysis, capital expenditures, policies and practices in public enterprises. Profit planning and programming, planning cash flow, capital expenditure and operations. Control of financial flows, control and communication.

Unit VI: Laws

Laws concerning entrepreneur viz, partnership laws, business ownership, sales and income taxes and workman compensation act. Role of various national and state agencies which render assistance to small scale industries.

References:

1) Khanka. S.S., Entrepreneurial Development, S. Chand& Co. Ltd.,Ram Nagar, New Delhi, 2013.
2) Donald F Kuratko, Entreprenuership – Theory, Process and Practice, 9th Edition, Cengage Learning 2014.
3) Forbat, John, Entrepreneurship, New Age International.
4) Havinal, Veerbhadrappa, Management and Entrepreneurship, New Age International
5) Joseph, L. Massod, Essential of Management, Prentice Hall of India.

Elective III: Product Design & Development

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

Prerequisites: Production Management

Course Outcomes: students will be able to

1. Carry out the basic engineering design process and also various techniques used for a product.
2. Construct the product development process and customer requirements, QFD.
3. Evaluate the performance measure of design and DFM of a product.
4. Perform the case study of product life cycle management of a product
5. Evaluate opportunity present in PLM as career option

Unit I: Engineering Product Design

Introduction to engineering design process, Industrial design, Importance of the engineering Design process, Types of designs, Engineering design process, A simplified iteration model, Design method versus scientific method, A problem-solving methodology, Considerations of a good design, Total life cycle, Regulatory and social issues, Description of design process, Conceptual design ,Embodiment design, Detail design, Planning for manufacture, Planning for distribution, Planning for use, Planning for retirement of the product.

Unit II: Embodiment Design

Product architecture, Modular product architecture, Implication of Architecture, Establishing the Architecture, Product configuration and concurrent engineering, Parametric design: steps, Failure Mode and Effect Analysis.

Unit III: Product Development Process:

Product life cycle, Generic product design process, Stage gate system of product development, Product Development process flow, Types of products, Product planning, Product planning process, Markets and marketing, Functions of marketing department, Element of marketing plan, Product development Economics.

Unit IV: Identifying Customer Needs

Identifying customer needs, Voice of customers, preliminary research on customers' needs, Gathering information from customers, Customer requirements, Differing views of customer requirements, Classifying customer requirements, Kano model, Establishing the engineering characteristics, Benchmarking in general, Competitive performance benchmarking, Reverse engineering or product dissection, Determining engineering characteristics, Quality function deployment, The house of quality, Steps for building a house of quality.

Unit V: Design for X

Design for Manufacture (DFM) and Design for Assembly (DFA): DFM guidelines, Specific design rules, Overview of DFM process, Design of castings**:** Guidelines for the design of castings, Producing quality Castings ,Design of forgings: DFM guidelines for closed-die forging, Design for sheet-metal forming: sheet metal stamping, Sheet bending, Deep drawing, Design of machining, Design for Plastic processing: Injection Molding, Estimation of manufacturing cost, Minimize the system complexity.

Unit VI: PLM

Introduction to PLM, Opportunity & benefits of PLM, Components of PLM, PLM vision, Structure for PLM vision, PLM strategy, Product Data Management, Case studies in PLM (Auto Industry & Home appliances)

Text Books

1. Karl T. Ulrich & Steven D. Eppinger., Product Design & Development, McGraw Hill, 3rd Edition, 2003,ISBN: 978–0– 07–014679–2
2. Dieter and Schmidt , Engineering Design, McGrawHill,2013, ISBN: 978–0– 07–283703–2
3. John Stark, Product Life Cycle Management:21st Century Paradigm for Product Realization,

Springer,2005,ISBN 1852338105

Reference Books

1. Tim Jones, Butterworth Heinmann, New Product Development by Oxford, TAC- 1997.
2. Roland Engene Y., Inetoviez, New Product Development: Design & Analysis, John Wiley and Sons Inc., N.Y. 1990.
3. Keyinotto and Kristini Wood, Product Design Pearson Education 2004.
4. ISO Standard: 9001:2008: Clauses 7.1, 7.2, 7.3

Elective IV: Automobile Engineering

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

Pre-requisites: Elements of Mechanical Engineering, kinematics of manufacturing machines, Theory of machines

Course Outcomes:

1. Recognize the fundamentals and applications of various types of automobiles and its major components
2. Identify engine components and subsystems; explain working of engine, formation and control of pollutants.
3. Illustrate the importance and working of transmission and driveline components
4. Explore components and working of steering, braking and suspension system and various types of tyres.
5. Demonstrate the importance and functioning of various electrical, electronic devices and recent trends in automobiles
6. Express the need and functioning of passenger safety equipment in automobiles and vehicle aerodynamics

Unit I: Introduction to Automobile Engineering & Safety

Introduction: Classification of automobiles, Major components and their functions. Chassis types, Different vehicle layout, Vehicle Dimensions., Aerodynamic body shapes & advantages
Vehicle safety: Necessity, active and passive safety, Restrain Systems (seatbelts), Air Bags, structural Components for Safety. Safety Glasses, Crumple Zone, antiroll bars.
Vehicle Pollution Control: cause and types of Emissions from Vehicle, Euro and Bharat Stage norms, Methods to reduce vehicular pollution, after treatment devices, Catalytic Converter

Unit II: Fuel Supply System and Cooling System

Fuel Supply systems: Necessity, Introduction to Carburetor and Fuel Injection in SI Engine CRDi, GDI, fuel injection system in CI engine: solid injection system, Fuel injection Pump, Study of Injectors
Cooling System: necessity of cooling, under cooling, overcooling, types of cooling system components, working of pressurized force &thermostatic, coolant additives

Unit III: Lubrication and Ignition System

Lubrication system- objective of lubrication, types of lubricants, properties and additives, types of lubrication systems- dry sum, wet sum and mist sum lubrication, crank case ventilation (Globe eye), SAE viscosity index.
Ignition System – battery, magneto and electronic ignition system, comparison, different starting system used in automobiles

Unit IV: Transmission Systems:
Clutch: Necessity, requirements of a clutch system. Types of Clutches, Gear box - Necessity of transmission, principle, types of transmission, Automatic Transmission.
Transmission system: Propeller shaft, Universal joint, constant velocity joint, Differential, 2 Wheel Drive, 4Wheel drive.
Steering systems: Principle of steering, steering geometry and wheel alignment, Power Steering. Under steer, Over steer.

Unit V: Suspension, steering system and Automotive Electronics

Tyres:tyres specification, types, factors affecting tyre performance, Special tyres, tyre treads, Hydroplaning., tyre Rotation.

Suspension systems: Need, Function of spring and shock absorber, conventional suspension, Independent suspension System, Active suspensions.

Brakes: Function,Classification, BasicComponents.DrumBrakes,DiscBrakes,Hydraulicbrakes,AirBrakes,ABS

Automotive Electronics: Dashboard instrumentation, Sensors used in automobiles, ECU Automotive Lighting: Importance, types and specifications, LEDs, Reflectors, Intelligent lighting, EMS

Unit VI: Recent Advances in automobile technology

Recent Advances in automobile technology: Electric Vehicle, Hybrid Cars, types of hybrids, Micro Hybrid. Traction control, intelligent highway system, Collision avoidance system, Automatic Cruise Control, Navigational aids, Parking Assistance system. Vehicle maintenance and troubleshooting.

Text Books

1. Ganesan V., "Internal Combustion Engines", Tata McGraw Hill Publishing CompanyLtd, Ninth Edition, New Delhi, 1995.
2. Mathur M.L., and Sharma R. P., "A course in I.C. Engine", Dhanpat Rai Publication,Seventh Edition, New Delhi, 1999.
3. Singh Kirpal, "Automobile Engineering – Vol II", New Chand Jain", Seventh Edition,Delhi, 1996.
4. Narang G. B. S., "Automobile Engineering", S. Chand and Company Ltd, Fifth Edition,Delhi, 1995.
5. Ballancy P. L., "Internal Combustion Engines", Khanna Publishers, Third Edition, NewDelhi, 1991.
6.Motor Vehicle Technology -- J.A. Dolan, Heinemann Educational Books

Reference Books

1. Heywood: Internal combustion Engine Fundamentals, Tata McGraw-Hill
2. Domkundwar & Domkundwar : Internal combustion Engine, Dhanpat rai
3. Joseph Heitner, "Automotive Mech

Elective IV: IOT and Machine Learning

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

Pre-requisites: Statistics and Numerical Methods, Sensors Technology, Artificial Intelligence for Robotics

Course outcomes:

Student will be able to:

1. Exemplify characteristics of IOT and its challenges
2. Develop IOT tools
3. Make use of embedded system platform to develop sensor based applications
4. Categorize machine learning techniques
5. Explore deployment and service models of cloud computing

Unit 1: Introduction to IoT

Defining IoT, Characteristics of IoT, Applications of IoT, Functional blocks of IoT, Communication models & APIs, Challenges in IoT: Design challenges, Development challenges, Security challenges, other challenges, Enabling technologies

Unit 2: Network and Communication aspects

Wireless medium access issues, MAC protocol survey, Survey routing protocols, Sensor deployment & Node discovery, Data aggregation & dissemination

Unit 3: Developing IoTs

Introduction to different IoT tools, developing applications through IoT tools, developing sensor based application through embedded system platform, Implementing IoT concepts with python

Unit 4: Supervised Machine learning:

Classification: Linear classifiers, Quadratic classifiers, Support vector machines, Random forests.

Regression: Least square, gradient descent, Lasso regression, Ridge regression

Unit 5: Un-Supervised Machine learning:

Clustering: K-means clustering-centroid based, density based, distribution based, Hierarchical clustering
Association: Apriori algorithm, Eclat algorithm, FP growth algorithm

Unit 6: Cloud computing:

Introduction to cloud computing, virtualization, Cloud deployment techniques, Architecture of cloud application, cloud programming, adoption and use of cloud.

References:

1. Vijay Madisetti, ArshdeepBahga, “Internet of Things: A Hands-On Approach” 2014. ISBN: 978-0996025515
2. Cloud Computing Bible, Barrie Sosinsky, Wiley and Sons,2011, ISBN: 9781118023990
3. Jamil Y. Khan, Mehmet R. YuceInternet of Things (IoT): Systems and Applications, CRC Press, 2019, ISBN: 9780429678059
4. BK Tripathy, J Anuradha , Internet of Things (IoT): Technologies, Applications, Challenges and Solutions, CRC Press, 2017. ISBN: 9781351980296
5. EthemAlpaydin Introduction to Machine Learning Adaptive computation and machine learning, MIT Press, 2004, ISBN: 9780262012119
6. Miroslav Kubat,An Introduction to Machine Learning, Springer, 2017. ISBN: 9783319639130

Elective IV: Supply Chain Management

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

Pre-requisites: Industrial Engineering and Management

Course Outcomes

After Successful completion of this course student will able to:

1. Build and manage a competitive supply chain using strategies, models, techniques and information technology.
2. Apply the method for strategic sourcing.
3. Apply cost effective solution for warehousing.
4. Optimize supply chain network.
5. Plan the demand, inventory and supply.

UNIT I: Introduction

Supply Chain – Fundamentals –Evolution- Role in Economy - Importance - Decision Phases - Supplier-Manufacturer-Customer chain. - Enablers/ Drivers of Supply Chain Performance. Supply chain strategy - Supply Chain Performance Measures.

UNIT II: Strategic Sourcing

Outsourcing – Make Vs buy - Identifying core processes - Market Vs Hierarchy - Make Vs buy continuum – Sourcing strategy - Supplier Selection and Contract Negotiation. Creating a world class supply base- Supplier Development - World Wide Sourcing.

UNIT III: Warehouse Management

Stores management-stores systems and procedures-incoming materials control-stores accounting and stock verification obsolete, surplus and scrap-value analysis-material handling-transportation and traffic management - operational efficiency-productivity-cost effectiveness-performance measurement

UNIT IV: Supply Chain Network

Distribution Network Design – Role - Factors Influencing Options, Value Addition – Distribution Strategies – Models for Facility Location and Capacity allocation. Distribution Center Location Models. Supply Chain Network optimization models. Impact of uncertainty on Network Design - Network Design decisions using Decision trees.

UNIT V: Planning Demand, Inventory and Supply

Managing supply chain cycle inventory. Uncertainty in the supply chain –- Analyzing impact of supply chain redesign on the inventory - Risk Pooling - Managing inventory for short life - cycle products -multiple item - multiple location inventory management. Pricing and Revenue Management

UNIT VI: Current Trends

Supply Chain Integration - Building partnership and trust in SC Value of Information: Bullwhip Effect – Effective forecasting - Coordinating the supply chain. . SC Restructuring - SC Mapping - SC process restructuring, Postpone the point of differentiation – IT in Supply Chain - Agile Supply Chains -Reverse Supply chain. Agro Supply Chains.

Text Books

1. Janat Shah, Supply Chain Management – Text and Cases, Pearson Education, 2009.
2. Sunil Chopra and Peter Meindl, Supply Chain Management-Strategy Planning and Operation, PHI Learning / Pearson Education, 2007.

References

1. Ballou Ronald H, Business Logistics and Supply Chain Management, Pearson Education, 5 th Edition, 2007.
2. David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi, Designing and Managing the Supply Chain: Concepts, Strategies, and Cases, Tata McGraw-Hill, 2005.
3. Altekar Rahul V, Supply Chain Management-Concept and Cases, PHI, 2005.
4. Shapiro Jeremy F, Modeling the Supply Chain, Thomson Learning, Second Reprint , 2002.
5. Joel D. Wisner, G. Keong Leong, Keah-Choon Tan, Principles of Supply Chain Management- A Balanced Approach, South-Western, Cengage Learning 2008.

Elective IV: Reliability Engineering

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

Pre-requisites: Metrology and Quality Control, Statistics and Numerical Methods,

Outcomes:

After learning this subject, the student will able to:

1. Identify and analyze the static and dynamic reliability of complex systems.
2. Identify commonly used reliability techniques using graphical techniques and empirical distributions.
3. Utilize common physical models for reliability analysis.
4. Perform reliability analysis of complete data.
5. Acquire ability to find root cause, correct, and document system failures.
6. Implement accelerated and highly accelerated life testing analyses

Unit I: Fundamentals of Reliability Engineering

Reliability definition, reliability concept, quality, failure, patterns of failure, causes of failure, Time to failure Distributions–experimental, Weibull, gamma, normal, log normal, extreme value, model selection for components failure, failure analysis. failure density, failure rate, hazard rate, MTTF, MTBF,MTTR, MDT, unreliability, factor of safety and reliability, areas of reliability, life characteristic phases, bath-tub curve, Elements of Probability theory: Set theory, total probability theorem, Bayes rule.

Unit II: System reliability and modeling

Series, parallel, mixed configuration, k- out of n structure, complex systems- enumeration method, conditional probability method, matrix method, cut-set and tie-set method, Redundancy, element redundancy, unit redundancy, standby redundancy- types of standby redundancy, parallel components single redundancy, multiple redundancy. Markov analysis.

Unit III: Maintainability and Availability

Objectives of maintenance, types of maintenance, Maintainability, factors affecting maintainability, system down time,

Availability - Inherent, Achieved and Operational availability, reliability and maintainability trade-off.

Unit IV: System reliability Analysis

Reliability allocation or apportionment, Reliability apportionment techniques – equal apportionment, AGREE, ARINC, feasibility of objectives apportionment, dynamic programming apportionment, Evaluation of overall system reliability, Reliability block diagrams and models, Reliability predictions from predicted unreliability, minimum effort method.

Unit V: Failure Mode, Effects and Criticality Analysis

Failure mode effects analysis, severity/criticality analysis, FMECA examples, RPN, Ishikawa diagram for failure representation, fault tree construction, basic symbols development of functional reliability block diagram, fault tree analysis, fault tree evaluation techniques, minimal cut set method, Delphi methods, Monte carlo evaluation.

Unit VI: Reliability testing and Failure Interactions and Terro-technology

Reliability growth models, grouped and ungrouped data, censored data, accelerated life testing, Markov analysis of two independent components, reliability with standby system, multi component systems, DTMC and CTMS models. Terro-technology, application of terro technology.

Reference Books

1. Patrick D. T. O, Apos, Connor, Practical Reliability Engineering 4th Edition, Willey, 2008
2. L.S. Srinath, Reliability Engineering, EWP East-West Press, 2005
3. Beyer Betsy, Site Reliability Engineering - How Google Runs Production Systems, Shroff Publishers & Distributors Pvt Ltd, 2016, ISBN: 9789352133628
4. Ebeling Charles, AN Introduction to Reliability and Maintainability Engineering, 2015, ISBN: 9780070421387

Industrial Robotics and Material handling Systems Lab

Teaching Scheme	Credit Scheme	Examination Scheme
Practical:2 hours / week	Practical: 01	TW: 25 Marks PR: 50 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

Field and Service Robotics Lab.

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 02 hours / week	Practical: 01	TW: 25 Marks OR: 50 Marks

Oral will be based on any five assignments from following

1. Need for service robot.
2. Experiment on robot kinematics.
3. Probabilistic Map based Localization-Monte carlo localization
4. Global & Local path planning in robotics.
5. Assignment on Metrical maps - Grid maps - Sector maps – Hybrid Maps.
6. Case study on Human activity recognition using vision, touch, sound etc.

Project Stage-II

Teaching Scheme	Credit Scheme	Examination Scheme
Practical: 12 hours / week	Pr/Or: 06	Termwork: 100 Marks Oral: 50 Marks

A per submitted project phase II plan to complete it within the time schedule, the term work shall consist of:

A detailed report to be prepared based on any one of the following topics

i. Manufacturing / Fabrication of a prototype Robotic / Automated system including selection, concept, design, material, manufacturing the components, assembly of components, testing and performance evaluation.

ii. Improvement of existing Robotic / Automated system.

iii. Design and fabrication of end effectors for robot

iv. Computer aided design, analysis *of* components such as stress analysis.

v. Modeling and Simulation of Robotic and Automation systems

vi. Robot Kinematics and Dynamic analysis

vii. Low cost automation, Computer Aided Automation in Manufacturing.

viii. Ergonomics and safety aspects of robotic systems

ix. Management Information System.

x. Product design and development

xi. Jigs and Fixtures, dies, tools, special purpose equipment, inspection gauges, measuring instruments for machine tools.

xii. Problems related to Productivity improvements / Value Engineering / Automated Material Handling Systems

Two copies of Final Project Report shall be submitted to the college. The students shall present their Final Project Phase-II report. Before the examiners. The oral examination, shall be based on the term work submitted and jointly conducted by an internal and external examiner from industry, at the end of second semester.

Format of the project report should be as follows:

1 Paper: The Project report should be typed / printed on white paper of A-4 size.

2 Typing: The typing shall be with one and half spacing and on both sides of the paper.

3 Binding: The Industrial Implant Report should be submitted with front and back cover in black Hard bound, with golden embossing

4 Margins: Left -1.25", Right -1". Top and Bottom 1"

5 Sequence of Pages

- 5.1 Title page
- 5.2 Certificate form Institute
- 5.3 Completion Certificate form Industry, if sponsored.
- 5.4 Acknowledgement
- 5.5 Abstract
- 5.6 Index
- 5.7 Nomenclature and Symbols

5.8 Actual Content
5.9 Conclusion
5.10 References.

6. Front cover: The front cover shall have the following details in block capitals

i. Title at the top.

ii. Name of the candidate in the centre, and

iii. Name of the Institute, Name of Industry, if sponsored and the year of submission on separate lines, at the bottom.

1 Blank sheets: No blank sheets be left anywhere in the report.

2 Project Completion Certificate: The approval sheet follows the title sheet and shall be as shown with proper spacing.

CERTIFICATE

This is to certify that Mr. /Ms ……(Name)……has carried out a Project entitled, ……during the course of his training at……..in partial fulfillment of the requirement of the B.E. Robotics and Automation Course of University of Pune at ……during the academic Year ……

Date:

Place:

(Guide) (Head of Department)

(Principal) (Examiner)