Semester-7th
Automation and Robotics

RA-401A	CNC MACHINE AND METROLOGY						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3 h**
Purpose	Understand evolution and principle of CNC machine tools. Write simple programs for CNC turning and machining centers. Generate CNC programs for popular CNC controllers. Describe about linear and angular measurements in metrology. Study about the advancement in metrology						
Course Outcomes: After studying the course, students will be able to:							
CO 1	Ability to know about the basic in CNC machineries						
CO 2	Evolution and principle of CNC machine tools and different measurement technologies						
CO 3	Able to write simple programs for CNC machinery						
CO 4	To impart knowledge about linear and angular measurements in metrology						

UNIT-1

INTRODUCTION TO CNC MACHINE TOOLS-Evolution of CNC Technology, principles, features, advantages, applications, CNC and DNC concept, classification of CNC Machines–turning centre, machining centre, grinding machine, EDM, types of control systems, CNC controllers, characteristics, interpolators– Computer Aided Inspection, CNC Machine building, structural details, configuration and design, guideways–Friction, Antifriction and other types of guideways

DRIVES AND WORK HOLDING DEVICES-Spindle drives—DC shunt motor, 3 phase AC induction motor, feed drives – stepper motor, servo principle, DC and AC servomotors, Axis measuring system — synchro, synchro resolver, gratings, moiré fringe gratings, encoders, inductosyn, laser interferometer, work holding devices for rotating and fixed workparts, economics of CNC, maintenance of CNC machines

UNIT-2

CNC PROGRAMMING-Coordinate system, structure of a part program, G & M Codes, tool length compensation, cutter radius and tool nose radius compensation, do loops, subroutines, canned cycles, mirror image, parametric programming, machining cycles, programming for machining centre and turning centre for well known controllers such as Fanuc, Heidenhain, Sinumerik etc, generation of CNC codes from CAM packages.

UNIT-3

LINEAR AND ANGULAR MEASUREMENTS-Linear Measuring Instruments – Evolution – Types Classification – Limit gauges – gauge design –terminology – procedure – concepts of interchange ability and selective assembly – Angular measuring instruments–Types–Bevel protractor clinometers angle gauges, spirit levels sine bar –Angle alignment telescope– Autocollimator–Applications.

UNIT-4

ADVANCES IN METROLOGY -Basic concept of lasers, Advantages of lasers, laser Interferometers, types, DC and AC Lasers interferometer, Applications, Straightness, Alignment. Basic concept of CMM, Types of CMM, Constructional features, Probes, Accessories, Software, Applications, Basic concepts of Machine Vision System, Element, Applications

TEXT BOOKS:

1. "Mechatronics", HMT, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2005.
2. Warren S. Seamers, "Computer Numeric Control", Fourth Edition, Thomson Delmar, 2002.
3. Jain R.K."Engineering Metrology", Khanna Publishers, 2005.
4. Gupta. I.C., "Engineering Metrology", Dhanpat Rai Publications, 2005.

REFERENCE BOOKS:

5. Charles Reginald Shotbolt, "Metrology for Engineers", 5th edition, Cengage Learning EMEA, 1990.
6. Backwith, Marangoni, Lienhard, "Mechanical Measurements", Pearson Education, 2006.
7. Peter Smid, "CNC Programming Handbook", IndustrialPressInc.,2000
8. Berry Leathan–Jones, "Introduction to Computer Numerical Control", Pitman, London, 1987.
9. Radhakrishnan P "Computer Numerical Control Machines", New Central Book Agency, 2002.

RA-403A	AUTOMATION SYSTEM DESIGN						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3 Hr.**
CO1	Understand what Automation System Design are used for today, and what is required for industrial automation						
CO2	Understand the types of systems that are available and in use today and can beutilized to implement Automated Systems.						
CO3	Be exposed to pneumatic, electric, hydraulic and electronic systems in automation of mechanical operations.						
CO4	Apply these technologies to tackle scenarios in teams of using an experimental platform for implementing prototypes and testing them as running applications. Understand about the advancement in hydraulics and pneumatics						

UNIT- I

FUNDAMENTAL CONCEPTS OF INDUSTRIAL AUTOMATION : Fundamental concepts in manufacturing and automation, definition of automation, reasons for automating. Types of production and types of automation, automation strategies, levels of automation.

UNIT- 2

TRANSFER LINES AND AUTOMATED ASSEMBLY: General terminology and analysis, analysis of transfer lines without storage, partial automation. Automated flow lines with storage buffers. Automated assembly-design for automated assembly, types of automated assembly systems, part feeding devices, analysis of multi-station assembly machines. AS/RS, RFID system, AGVs, modular fixturing. Flow line balancing.

UNIT-3

DESIGN OF MECHATRONIC SYSTEMS

Stages in design, traditional and mechatronic design, possible design solutions. Case studies-pick and place robot, engine management system.

UNIT-4

PROGRAMMABLE AUTOMATION

Special design features of CNC systems and features for lathes and machining centers. Drive system for CNC machine tools. Introduction to CIM; condition monitoring of manufacturing systems.

DESIGN FOR HIGH SPEED AUTOMATIC ASSEMBLY

Introduction, Design of parts for high speed feeding and orienting, high speed automatic insertion. Analysis of an assembly. General rules for product design for automation.

TEXT BOOKS:

1. Mikell P Groover, “Automation Production Systems and Computer- Integrated Manufacturing” Pearson Education, New Delhi, 2001.
2. Bolton W, “Mechatronics“, Pearson Education, 1999.

REFERENCES:

1. Mikell P Groover, "Industrial Robots – Technology Programmes and Applications” , McGraw Hill ,New York, USA. 2000.
2. Steve F Krar, “Computer Numerical Control Simplified“, Industrial Press, 2001.
3. Joffrey Boothroyd, Peter Dewhurst and Winston A. Knight, “Product Design for manufacture and Assembly”, CRC Press, 2011

RA-405 LA	Advanced Robotics Lab						
Lecture (Hrs.)	**Tutorial (Hrs.)**	**Practical (Hrs.)**	**Credit**	**Practical**	**Minor Test**	**Total**	**Time**
-	**-**	**2**	**1**	**60**	**40**	**100**	**3 Hrs.**

Course Outcomes (CO)

To give the students an idea about the 8051/PIC/Ardiuno/AVR/ARM microcontrollers

CO1	To illustrate the design and simulation of multiple Sensors.
CO2	To design a system using **Ardiuno**
CO3	To design a Microcontroller kit with stepper motor and drive circuit using LABVIEW software
CO4	To expose the students in sensors/actuators interfaced with computers.

LIST OF EXPERIMENTS:

1. Programming of HCS12 with Code warrior for Interrupts, Clock Functions,
2. TIM, RTI, SPI, LCD interfacing,
3. Use of JTAG and Hardware Debuggers, Interfacing Keypad,
4. ADC, DAC, LCD, Real Time Clock
5. Temperature Sensors with I2C and SPI bus
6. Interface 7 segment LED to 8051 to generate flashing action
7. Interface Analog to Digital converter to 8051 and display the result on LCD display
8. Interface Digital to Analog converter to 8051 and view the output on CRO Interface stepper motor to 8051 it through given number of steps
9. Perform serial communication using 8051
10. Decentralized motion control and Centralized motion control
11. Feed-forward compensation,
12. Force control,
13. Stepper motor control (Single motor and two motor).
14. Linear controller (P, PI, PD and PID) design for simple position control of mechanical systems.

RA-407LA	Automation System Design Lab						
Lecture (Hrs.)	**Tutorial (Hrs.)**	**Practical (Hrs.)**	**Credit**	**Practical**	**Minor Test**	**Total**	**Time**
-	**-**	**2**	**1**	**60**	**40**	**100**	**3 Hrs.**

Course Outcomes (CO)
To give the students an idea about the PNEUMOSIM software , 8051/PIC/AVR/ARM microcontrollers

CO1	To illustrate the design and simulation of multiple actuator systems using pneumatic, electropneumatic and PLCs and enable the students to integrate various fringe conditions in multiple actuator systems
CO2	To design a system using PNEUMOSIM software
CO3	To design a Microcontroller kit with stepper motor and drive circuit using LABVIEW software
CO4	To expose the students in sensors/actuators interfaced with computers.

LIST OF EXPERIMENTS:

1. Co-ordinated motion of multiple pneumatic actuators in a desired sequence using Cascade method
2. Integration of fringe condition modules in multiple actuator pneumatic systems
3. Co-ordinated motion of multiple actuator, electro – pneumatic systems in a desired sequence using hard – wire programmed control systems
4. Co-ordinated motion of multiple actuator, electro – pneumatic systems in a desired sequence using PLC.
5. Interfacing of an LVDT with a PC for monitoring the displacement of machine slide and raising an alarm if the displacement exceeds specified limit.
6. Inspection using Machine vision System
7. Control of speed, direction and number of revolutions of a stepper motor using PC.
8. Development of an obstacle avoidance robot using servo motors, ultrasonic and touch sensors.
9. Trajectory planning and analysis
10. Pick and place / path tracking using robot

B.Tech 7th Semester Automation and Robotics

Project-III (RA-409 LA)

L: T: P: 0:0:6

Credits: 3

Course Objectives

The course should enable the students:

1. To identify a suitable and relevant topic which can be developed either through development or research activities and match the level expected of an undergraduate student.
2. To identify and collate relevant information pertaining to the project's requirements from various resources.
3. To plan, design and propose a feasible project based on the given timeline.

Course Outcomes

At the end of the course, the student will be able to:

CO1: Identify and define a problem based on the community/industry/research.

CO2: Plan project activities, considering their underlying requirements, constraints and deliverables. CO3: Design the solution to the identified problem.

CO4: Communicate and document the project work through technical reports and presentations.

Guidelines

The aim of the final year project is to give students opportunity to apply the knowledge they have gained to solve practical engineering problems. By doing so, students will gain knowledge and experience in solving problems systematically thus when they graduate, they will be ready to work as reliable and productive engineers. The project problem may be a theoretical analysis, modeling & simulation, experimentation & analysis, prototype design, fabrication of new equipment, correlation and analysis of data, software development, etc. or a combination of these.

In project phase 1, students are recommended to conduct an exhaustive literature survey to identify the real-life problems. Based on the literature survey they should formulate the problem statement and identify the methodology utilized to solve the problem. At the end of phase 1 of the project, students will have to document their work in the form of project report in the prescribed form. The final evaluation and viva-voce will be conducted after submission of the final project report. Students have to make a presentation on the work carried out, before the departmental committee, as part of project evaluation.

RAO-401A	FUNDAMENTALS OF IOT AND ITS APPLICATIONS						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3 h**
Course Outcomes: After studying the course, students will be able to:							
CO 1	Understand the drivers and enablers of Industry 4.0.						
CO 2	Appreciate the smartness in Smart Factories, Smart cities, smart products and smart services.						
CO 3	Able to outline the various systems used in a manufacturing plant and their role in an Industry						
CO 4	Appreciate the power of Cloud Computing in a networked economy.						
CO5	Understand the opportunities, challenges brought about by Industry 4.0 and how organizations and individuals should prepare to reap the benefits.						

UNIT-1

IoT Foundations- Introduction to Internet of Things, An Overview Introduction – Definition and characteristics of IoT, Physical design of IoT- Things in IoT, IoT protocol, Logical design of IoT – IoT functional blocks, IoT Communication Models, Introduction to SDN, SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud, Fog Computing, Examples of IoT based Systems: Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT.

UNIT-2

IoT Architecture and its Protocols- Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications, Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Introduction to Python programming, Introduction to Raspberry Pi, Implementation of IoT with Raspberry Pi.

UNIT-3

Sensors for IoT- Sensing and actuation, types of sensors, Occupancy Sensors, Motion sensor, velocity, temperature, pressure, chemical, Gyroscopic sensor, Optical sensors, Humidity, Water Quality sensors, Sensor applications.

Actuator for IoT-Actuator types, working principle of actuators, integration of sensors and actuators with Arduino, formation of actuators, selection criteria for right actuator, maintenance of actuators, smart material actuators.

UNIT-4

Applications of IoT in Robotics- Future farming with the Internet of things, drones for surveillance, Soft low-power robotics, Tracking sensors for underwater robotics, Disaster response, Medical services, Smart restaurant, Analysis of IoT applications and Sensors, Space robotics for science and space exploration, Satellite based Internetworking, Tele operators, Space component systems like rover mobility, locomotion and guidance.

Future of Robotics with IOT-Powering insect-scale wireless robotics, Big data analysis, Augmented Reality, Additive manufacturing, Cyber security, the industrial internet of things, the cloud, Horizontal and vertical system integration, simulation, Autonomous robot.

TEXT BOOKS:

1. Dr. Jeeva Jose, Internet of Things, Khanna Book Publishing (khannabooks.com), 2021.
2. Vijay Madisetti and Arshdeep Bahga, Internet of Things (A Hands-on Approach), 1st Edition, VPT, 2014.
3. Korf Richard, “Space Robotics”, Carnegie-Mellon University, the Robotics Institute, 1982.

REFERENCE BOOKS:

1. Lewin A.R.W. Edwards, “Open source robotics and process control cookbook”, Elsevier Publications, 2005.
2. Francis DaCosta, Rethinking the Internet of Things: A Scalable Approach to Connecting Everything, 1st Edition, A press Publications, 2013.
3. Wimer Hazenberg, Menno Huisman and Sara Cordoba Rubino, Meta Products: Building the Internet of Things, BIS publishers, 2012.
4. Pethuru Raj and Anupama C. Raman, The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press, 2017.
5. Arshdeep Bahga and Vijay Madisetti Internet of Things: A Hands-on Approach", Universities Press, 2014.

RAO-403A	INDUSTRY 4.0						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3 h**
Course Outcomes: After studying the course, students will be able to:							
CO 1	know about Industry 4.0 and its scope.						
CO 2	explain Design thinking principles and its usage for problem solution						
CO 3	use various tools and technologies.						
CO 4	apply learned skills to approach problems that exist in real life						

UNIT-1

Introduction to Industry 4.0- The various industrial revolutions, digitalization and the networked economy, drivers, enablers, comparison of industry 4.0 factory and today's factory, trends of industrial big data and predictive analytics for smart business transformation.

Road to Industry 4.0- Internet of Things (IoT) & Industrial Internet of Things (IIoT) & Internet of Services, Big data, Value chains in Manufacturing companies, Smart factories, Smart Devices and Products, Smart Logistics, Smart Cities, smart services, Predictive Analytics, Case studies.

UNIT-2

Technologies for Enabling Industry 4.0- Cyber Physical Systems, Robotic Automation and Collaborative Robots, Support System for Industry 4.0, Mobile Computing, Cyber Security, Augmented / Virtual reality, Artificial Intelligence, System integration, digital twin, 3D printing, Case studies.

Industry 4.0 Design Principles- Introduction to Industry 4.0 design principles – Interoperability, Communication systems and standards for Industry 4.0, virtualization, Decentralization, Modularity, real time capability, information transparency– Foundation of Industry 4.0 - Cloud Manufacturing and the connected factories.

UNIT-3

Impact of Industry 4.0- Impact of Industry 4.0 on – service and business models, IT security, manufacturing, machine safety, product life cycle, socio economic factors, textile industries, healthcare industries, real estate industries, maritime industries, tourism industries - Compelling Forces and Challenges in implementing Industry 4.0. Case studies.

TEXT BOOKS:

1. Klaus Schwab, "The Fourth Industrial Revolution", Portfolio Penguin, 2017.
2. Bruno S.Sergi, Elena G.Popkova, Aleksei V. Bogoviz and Tatiana N. Litvinova, " Understanding Industry 4.0: AI, The internet of things, and the future of work", Emerald publishing limited, 2019.

REFERENCE BOOKS:

1. Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress, 2016.
2. Kaushik kumar, Divya Zindani, J. Paulo Davim, "Digital manufacturing and assembly systems in Industry 4.0", CRC Press, Taylor and Francis group, 2020.
3. Antonio sartal, Diego Carou, J.PauloDavim, " Enabling technologies for the successful deployment of Industry 4.0, CRC press, 2020.
4. Alp Ustundag, Emrecavikcan, " Industry 4.0 : Managing the digital transformation", Springer International publishing, 2018.
5. Christoph Jan Bartodziej, "The Concept Industry 4.0", Springer Gabler, 2017.

RAO-405 A	INDUSTRIAL SAFETY & STANDARDS						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	Students will be able to recognize and evaluate occupational safety and health hazards in the workplace, and to determine appropriate hazard controls following the hierarchy of controls. Students will furthermore be able to analyse the effects of workplace exposures, injuries and illnesses, fatalities and the methods to prevent incidents using the hierarchy of controls, effective safety and health management systems and task-oriented training						
Course Outcomes: After studying the course, students will be able to:							
CO1	Ability to know about occupational safety and health regulatory bodies.						
CO2	Ability to know about risk and hazard, their assessment, fire safety standards.						
CO3	Ability to know about hazard control, hierarchy, administrative controls, personal protective equipment and general industry safety hazards						
CO4	Ability to know about construction safety hazards.						

UNIT-I

Introduction to occupational safety and health regulatory bodies, research, requirements, and industry best practices: Department of Labor NFPA ANSI NEC Etc

UNIT-II

Hazard Recognition, Risk versus hazards, Hazard assessment tools, Site assessments, Job Hazard Assessments Fire and Life Safety, Fire Hazards, Fire Safety standards, Life Safety, Prevention and control

UNIT–III

Hazard Control, Hierarchy of Controls, Substitution / Elimination/ Engineering Controls Work Practices Administrative Controls, Personal Protective Equipment.

General industry safety hazards: Recognition and control in a manufacturing environment. Focusing on: Standards development, concepts, and application in manufacturing

UNIT–IV

Construction safety hazards: Recognition and control in a construction environment, Safety Analysis and Prevention Strategies, Analysis of hazards Prevention, Promoting safety Defining value

Reference Books

1. Relevant Federal Regulations; Occupational Safety and Health for Technologists, Engineers, and Managers; Goetsch, David 8 th edition (2014)(Prentice Hall);

2. Advanced Safety Management: Manuele, Fred, 2nd edition (2014) (Wiley Pres); additional selected readings and case studies.

Note: The paper setter will set the paper as per the question paper template provided.

RAP-401 A	INDUSTRIAL ROBOT APPLICATIONS						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	The objective of this course is to prepare and aware the students about various robot applications. Students will get an understanding about various industrial robotic applications used in the manufacturing industry. Students will understand about various welding processes. Students will learn about differences about MIG, TIG and spot-welding processes.						
Course Outcomes:	After studying the course, students will be able to:						
CO1	Ability to understand the industrial robot applications like Material handling, Processing Applications, Assembly applications, Inspection Application, Principles for Robot Application and Application planning, Justification of Robots, Robot Safety, Non-Industrial Applications						
CO2	Ability to understand the basics of arc welding, robot interfacing and programming.						
CO3	Ability to understand basics of spot welding, robot selection and integration.						
CO4	Ability to understand Spot welding process, process parameters and programming of spot welding robot.						

UNIT-I

Industrial Applications: Material handling, Processing Applications, Assembly applications, Inspection Application, Principles for Robot Application and Application planning, Justification of Robots, Robot Safety, Non-Industrial Applications

UNIT-II

Basics of Arc welding: Welding Guns, Welding Electrodes, Welding Power Sources, shielding gases, Robot interfacing, Types of Joints, Welding Parameters.
Application software, Robot Programming with Arc ware, Seam Tracking, Touch sensor, Quality parameters, tooling.

UNIT–III

Basics of Spot welding: Spot welding Gun, Spot welding Timer, Utilities, Robot selection, Integrating with Robots.

UNIT–IV

Application software (Spot ware), Spot welding Parameters, programming Robot with spot welding application. Spot welding instructions, Quality parameters, tooling.

TEXT BOOKS:

Text Books & Reference Books:

1. Robotics & Control – R.K. Mittal & I.J. Nagrath – TMH Publications
2. Welding Robots Technology, System Issues and Applications by J. Norberto Pires, Altino Loureiro and Gunnar Bölmsjo
3. Robotics for engineers - Yoram Korean- McGrew Hill Co.
4. Industrial Robotics Technology programming and Applications - M.P.Groover, M.Weiss, R.N.Nagel, N.G.Odrey.

Note: The paper setter will set the paper as per the question paper templates provided.

RAP-403 A	Mobile Robotics						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose							
Course Outcomes: After studying the course, students will be able to:							
CO1	Learn principles of working of mobile robots.						
CO2	Demonstrating the sensing, perception, and cognition of autonomous robots.						
CO3	Understand the anatomy of autonomous robots.						
CO4	Control the intelligent mobile robotic system						

UNIT-I

Introduction to the fundamentals of mobile robotics, basic principles of locomotion, Kinematics and Mobility, Classification of mobile robots, AI for Robot Navigation.

Introduction to modern mobile robots: Swarm robots, cooperative and collaborative robots, mobile manipulators, Current challenges in mobile robotics.

UNIT–II

Robot locomotion: Types of locomotion, hopping robots, legged robots, wheeled robots, stability, maneuverability, controllability; Mobile robot kinematics and dynamics: Forward and inverse kinematics, holonomic and nonholonomic constraints, kinematic models of simple car and legged robots, dynamics simulation of mobile robots;

UNIT–III

Autonomous Mobile Robots – need and applications, sensing, localisation, mapping, navigation and control. The Basics of Autonomy (Motion, Vision and PID), Programming Complex Behaviors (reactive, deliberative, FSM), Robot Navigation (path planning), Robot Navigation (localization), Robot Navigation (mapping), Embedded electronics, kinematics, sensing, perception, and cognition

UNIT–IV

Localization: Odometric position estimation, belief representation, probabilistic mapping, Markov localization, Bayesian localization, Kalman localization, positioning beacon systems;

Introduction to planning and navigation: path planning algorithms based on A-star, Dijkstra, Voronoi diagrams, probabilistic roadmaps (PRM), rapidly exploring random trees (RRT), Markov Decision Processes (MDP), stochastic dynamic programming (SDP);

TEXT BOOKS:

1. Nicolas Korell, “Introduction to Autonomous Robots”, MIT Press, 2016.
2. Sabrie Soloman, Advanced Robotics (Design & Applications), Khanna Book Publishing, 2023.
3. Roland Siegwart, Illah Reza Nourbakhsh, Davide Sacramuzza, Introduction to Autonomous Mobile Robots, MIT press, 2nd edition, 2011.
4. S. M. LaValle, “Planning Algorithms”, Cambridge University Press, 2006.

REFERENCES:

1. Designing Autonomous Mobile Robots, John M Holland, Elsevier, 2004.
2. Autonomous Mobile Robots,Edited by Shuzi Sam Ge, Frank L Lewis, Tylor and Francis, 2006
3. Peter Corke, Robotics Vision and Control, Springer 2011.

Note: The paper setter will set the paper as per the question paper template provided.

RAP-405 A	MODELLING & SIMULATION						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	The objective of this course is to give students an opportunity to learn concepts in modelling and simulation.						
Course Outcomes: After studying the course, students will be able to:							
CO1	Students will attain the knowledge of System and environment, concepts of Simulation & modelling, and statistics in simulation.						
CO2	Students will attain the knowledge of modelling elements in manufacturing systems & Simulation of manufacturing systems.						
CO3	Students will attain the knowledge of modelling of manufacturing supply chains.						
CO4	Students will attain the knowledge of Design of simulation experiments.						

UNIT-I

Introduction: Concept of System and environment, Continuous and discrete systems, Linear and non-linear systems, Stochastic processes, Static and Dynamic models, Principles of modeling, Basic Simulation modeling, Role of simulation in model evaluation and studies, Steps in a simulation study, Verification, validation and credibility of simulation models, Advantages, disadvantages and pitfalls of simulation. **Statistics in Simulation:** Review of basic probability and statistics, random variables and their properties, Statistical analysis for terminating simulation and steady state parameters

UNIT-II

Modelling Elements In Manufacturing Systems: Definition, Classifications and characteristics of production systems; measures of manufacturing systems performance, modelling elements in manufacturing systems: processes, resources, single and multi-server queues, arrival processes, service times, downtime, manufacturing costs, resources selection rules, different manufacturing flexibilities.
Simulation of Manufacturing Systems: Simulation of Job shop, batch and Flexible manufacturing systems, Case studies for above systems.

UNIT-III

Modelling of Manufacturing Supply Chains (SC): Introduction of SC, Modelling elements in SC, Measures of SC performance, brief review of bear game, SC initiatives and effect on SC performance Modelling of Supply Chain Processes at different Supply chain nodes like: Retailer, assembler, distributor, and manufacturer; Modelling of different SC processes, inventory control policies like (s, S), (s, Q) systems, production control issues like Manufacturing-to-order, Manufacturing-to-stock, Assemble-to-order, Assemble-to-stock; Modelling of material transport system in SC, Development of Simple SC models

UNIT-IV

Design of Simulation Experiments: Consideration For Selecting Length of Simulation run, no of replication and warm-up period, elimination of initial bias, Finance Considerations of a simulation study, Variance reduction techniques, 2k factorial design, fractional factorial design, factor screening, response surface, Meta-models and sensitivity, optimization procedures.

Text Books and Reference Books

1. Simulation Modeling and Analysis, 3e, Law A.M. and Kelton W.D., TMH, New Delhi.
2. Simulation with Arena - Kelton and Sadowski, 2003, (McGraw-Hill).
3. Analysis and Control of Production Systems, Printice Hall Publn, E.A. Elsayed and T.O.Boucher, 1994.

4. Modelling and Analysis of Dynamic Systems, C.M. Close and Dean K.F., Houghton Mifflin.
5. Simulation of Manufacturing, Allan Carrie, John Wiley & Sons.
6. System Simulation, Geoffrey Gordon, Prentice Hall, 1998.
7. Modern Production /Operations Management, 8e, Buffa E.S. and Sarin R.K., John Wiley.
8. Designing and Managing the Supply Chain, 3/e, Simchi-Levi D., Kaminsky P., Simchi- Levi E., Shankar R., TMH, New Delhi.

Note: The paper setter will set the paper as per the question paper template provided.

RAP- 407 A	MACHINE LEARNING FOR ROBOTICS						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	a) To understand the concepts of machine learning b) To understand the unsupervised learning, dimensionality concepts c)To learn the Concepts of neural networks in robots with case studies.						
Course Outcomes: After studying the course, students will be able to:							
CO1	Understand the concepts of machine learning						
CO2	Understand the concepts of supervised & unsupervised learning methods						
CO3	Understand the learning methodologies and dimensionality concepts						
CO4	Apply neural networks in robotic applications.						

UNIT-I

Introduction: Machine learning – Varieties of Machine learning – Learning Input- Output functions: Types of learning – Input Vectors – Outputs – Training regimes – Noise – Performance Evaluation.

UNIT-II

Foundations of Supervised Learning: Decision trees and inductive bias – Geometry and nearest neighbors – Logistic regression – Perceptron – Binary classification.

Advanced Supervised Learning: Linear models and gradient descent – Support Vector machines – Naïve Bayes models and probabilistic modeling – Model selection and feature selection – Model Complexity and Regularization.

UNIT–III

Unsupervised Learning: Curse of dimensionality, Dimensionality Reduction, PCA, Clustering – K-means – Expectation Maximization Algorithm – Mixtures of latent variable models – Supervised learning after clustering – Hierarchical clustering.

UNIT–IV

Neural Networks: Network Representation, Feed-forward Networks, Back propagation, Gradient-descent method.

Case Studies: Line following using Supervised Learning techniques – A simulation model for understanding both regression and classification techniques - Study of the effectiveness of the Bias-variance. Obstacle avoidance and navigation of a mobile robot in an unknown environment with the help of Neural Network -Use of stochastic PCA and the PCA neural network to find low dimensional features. Building a feed-forward neural network to ascertain automatic navigational queries.

TEXT BOOKS:

1. Michalski, Carbonell, Tom Mitchell, 'Machine Learning', Springer, 2014.
2. Peter Flach, 'Machine Learning: The Art and Science of Algorithms that make sense of data', Cambridge, 2014.

REFERENCE BOOKS:

1. Hal Daume III, 'A Course in Machine Learning', Todo, 2015.
2. EthemAlpaydin,'Introduction to Machine Learning',The MIT Press, 2004
4. Bruno Apolloni, Ashish Ghosh, FerdaAlpasian, "Machine Learning and Robot Perception", Springer, 2005.
5. Judy Franklin, Tom Mitchell, SebastinThrun, "Recent Advances in Robot Learning: Machine Learning", Springer, 2012.

Note: The paper setter will set the paper as per the question paper template provided.

RAP-409 A	ROBOTIC PROGRAMMING						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose							
Course Outcomes: After studying the course, students will be able to:							
CO1	Understand the basic principles of Robotics programming and development.						
CO2	Design real world applications using available software.						
CO3	Understand integration technologies and its applications.						
CO4	Identify problems in integrating the system / simulations / programming.						

UNIT-I

Introduction to ROS2: Architectural overview of the Robot Operating System, Framework and setup with ROS2 environment, ROS2 workspace structure, essential command line utilities. ROS2 nodes, topics, services, parameters, actions and launch files. Programming nodes, topics, services, actions with C/C++/Python. Real time programming with ROS2.

UNIT-II

Robot Simulation Engines: Physics simulations of Robots with Gazebo, Mujoco and Pybullet C++/Python APIs. Intro to Path Planning and Navigation, Classic Path Planning, Number of classic path planning approaches that can be applied to low-dimensional robotic systems. Coding the BFS and algorithms in C++. SampleBased and Probabilistic Path Planning and improvement using the classic approach. Programming in Moveit framework.

UNIT–III

Motion Planning, Mapping and SLAM: Use of the EKF ROS package to a robot to estimate its pose. Monte Carlo Localization: The Monte Carlo Localization algorithm which uses particle filters to estimate a robot's pose. Build MCL in C++: Coding the Monte Carlo Localization algorithm in C++. Simultaneous Localization and Mapping (SLAM) implementation with ROS2 packages and C++. Combining mapping algorithms with the localization concepts. Introduction to the Mapping and SLAM concepts and algorithms. Occupancy Grid Mapping: Mapping an environment with the Occupancy Grid Mapping algorithm. Grid-based FastSLAM: Simultaneous mapping an environment and localize a robot relative to the map with the Grid-based FastSLAM algorithm.

UNIT–IV

Concepts of microros, Client library, features of microros, real time operating systems (RTOS- Free RTOS, Zephyr), implementation of microros on ARM/ESP32 based microcontrollers.

TEXT BOOKS:

1. Sabrie Soloman, Advanced Robotics (Design & Applications), Khanna Book Publishing, 2023.
2. Aaron Martinez, Enrique Fernandez, "Learning ROS for Robotic Programming", PACKT publishing, 2013.
3. Morgan Quigley, Brian Gerkey, William D Smart, "Programming Robots with ROS", SPD Shroff Publishers and distributors Pvt. Ltd., 2016.
4. Lentin Joseph, "Mastering ROS for Robotics Programming: Design, Build and simulate complex robots using ROS", PACKT publishing, 2013

REFERENCES:

1. Anis Koubaa, "Robot Operating System", Springer link, 2016.
2. Anil Mahtani, "Effective Robotics Programming with ROS", Packt Publishing, 2016

Note: The paper setter will set the paper as per the question paper template provided.

RAP-411 A	ARTIFICIAL INTELLIGENCE & EXPERT SYSTEM IN AUTOMATION						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	To understand the basic concepts of artificial intelligence and to apply the acquired knowledge of AI in the robotics field.						
Course Outcomes: After studying the course, students will be able to:							
CO1	understand the basic concepts and techniques of Machine Learning						
CO2	apply Dimensionality reduction Techniques & AI in Robotics						
CO3	Use the tools and the processes for the creation of an expert system.						
CO4	Conduct an in-depth examination of an existing expert system with an emphasis on basic methods of creating a knowledge base.						

UNIT-1

History of AI- Introduction – History, Definition of AI, Emulation of human cognitive process, Intelligent agents – The concept of rationality, the nature of environments, the structure of agents.

UNIT-2

Foundations of Supervised Learning: Decision trees and Inductive bias – Geometry and nearest neighbors – Logistic regression – Perceptron – Binary classification.

Unsupervised Learning-Curse of dimensionality, Dimensionality Reduction, PCA, Clustering – K-means – Expectation Maximization Algorithm – Mixtures of latent variable models – Supervised learning after clustering – Hierarchical clustering – Case studies.

UNIT-3

Introduction, the history of knowledge-based expert systems, Characteristics of current expert systems, Basic concepts for building expert systems.

Building and Expert System, the architecture of expert systems, constructing an expert system, including computer inference and knowledge acquisition

UNIT-4

Knowledge representation schemes; conceptual data analysis; plausible reasoning techniques, Tools for building expert systems. Evaluating an Expert System, Reasoning about reasoning, validation and measurement methods

TEXT BOOKS:

1. Russell Stuart, Norvig Peter, "Artificial Intelligence Modern Approach", Pearson Education series in AI, 3rd Edition, 2010.
2. Artificial Intelligence for Robotics Build intelligent robots that perform human tasks using AI Techniques, Francis X. Govers, August 2018.
3. Peter Flach, Machine Learning: The Art and Science of Algorithms that make sense of data, Tom Mitchell, Machine Learning ', McGraw Hill, 2015.
4. Davis, R. & Lenat, D. B., "Knowledge-Based Systems in Artificial Intelligence", McGraw-Hill, 1989.
5. Hayes-Roth, F., Waterman, D. A. & Lenat, D. B. (eds) Building Expert Systems. Addison Wesley Pub. Comp., Inc., 1984.

REFERENCE BOOKS:

1. Dan. W. Patterson, "Introduction to Artificial Intelligence and Expert Systems", PHI Learning,2009.
2. Ethem Alpaydin,'Introduction to Machine Learning', The MIT Press, 2004
3. Hal Daume III,A course in Machine Learning', Todo, 2015.
4. Buchanan, B. B. & Shortliffe, E. H., "Building Expert Systems with Production Rules: The Mycin Experiments", Wesley Publishing Company, 1983.
5. Torsun, I. S. Expert Systems: State of the Art, Addison-Wesley Publishing Company, 1983

Note: The paper setter will set the paper as per the question paper template provided.

Semester-8th
Automation and Robotics

B.Tech 8th Semester Automation and Robotics

Project-IV (RA-402 LA)

L: T: P: 0:0:8

Credits: 4

Course Objectives

The course should enable the students to:

1. Develop the project identified in project phase 1 according to the proposed plan and design.
2. Verify and validate the developed projects against the proposed objectives and goals.
3. Propose future improvement based on project outcomes.
4. Communicate project ideas and final product through technical report and presentation.

Course Outcomes

At the end of the course, the student will be able to:

CO1: Develop and test the solution based on the methodology identified in the final year project phase 1.

CO2: Analyze and discuss the results to draw valid conclusions.

CO3: Demonstrate related deliverables needed to support and present the entire project effectively with written and oral means.

CO4: Understand and practice professional and ethical responsibilities for sustainable development of society in the chosen field of project.

CO5: Communicate and document the project work through technical report and presentations.

Guidelines

The aim of the final year project is to give students opportunity to apply the knowledge they have gained to solve practical engineering problems. By doing so, students will gain knowledge and experience in solving problems systematically thus when they graduate, they will be ready to work as reliable and productive engineers. The project problem may be a theoretical analysis, modeling & simulation, experimentation & analysis, prototype design, fabrication of new equipment, correlation and analysis of data, software development, etc. or a combination of these.

In phase 2 of the project work, students are recommended to prove the solution to the identified problem statement and methodology in phase 1. The solution should be in the form of fabrication/coding/modeling/ product design/process design/relevant scientific methodology. The consolidated report along with the developed model should be submitted for the assessment. Project outcome should be evaluated in terms of technical, economic, social, environmental, political and demographic feasibility. The

final evaluation and viva-voce will be conducted after submission of the final project report in the prescribed form. Students have to make a presentation on the work carried out, before the departmental committee, as part of project evaluation.

RAO-402A	TOTAL QUALITY MANAGEMENT						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	The purpose of this course is to develop an understanding of quality management framework, philosophies, in-depth knowledge of various tools and techniques with their application in the manufacturing and service industry.						
Course Outcomes: The student would be able to apply the tools and techniques of quality management to manufacturing and services processes.							
CO1	Students will be able to understand quality management philosophies and frameworks.						
CO2	Students will be able to describe various tools and techniques of quality management.						
CO3	Students will be able to explain the applications of quality tools and techniques in both manufacturing and service industry						
CO4	Students will be able to describe various quality systems like ISO and its standards.						

UNIT-1

INTRODUCTION- Introduction - Need for quality - Evolution of quality - Definitions of quality - Dimensions of product and service quality - Basic concepts of TQM - TQM Framework - Contributions of Deming, Juran and Crosby - Barriers to TQM - Customer focus - Customer orientation, Customer satisfaction, Customer complaints, Customer retention.

UNIT-2

TQM PRINCIPLES- Leadership-Quality Statements, Strategic quality planning, Quality Councils-Employee involvement-Motivation, Empowerment, Team and Teamwork, Recognition and Reward, Performance appraisal –Continuous process improvement -PDCAcycle,5S,Kaizen-Supplierpartnership-Partnering,Supplier selection, Supplier Rating.

UNIT-3

TQMTOOLS AND TECHNIQUES- The seven traditional tools of quality - New management tools - Six sigma: Concepts, Methodology, applications to manufacturing, service sector including IT - Bench marking - Reason to bench mark, Benchmarking process-FMEA-Stages, Types. Quality Circles - Cost of Quality - Quality Function Deployment (QFD) - Taguchi quality loss function -TPM-Concepts, improvement needs –Performance measures.

UNIT-4

QUALITY MANAGEMENT SYSTEM-Introduction, Benefits of ISO Registration, ISO9000 Series of Standards, Sector-Specific Standards, AS9100, TS16949 and TL9000, ISO9001 Requirements, Implementation, Documentation, Internal Audits, Registration

ENVIRONMENTAL MANAGEMENT SYSTEM- Introduction, ISO 14000 Series Standards, Concepts of ISO 14001, Requirements of ISO 14001, Benefits of EMS.

TEXT BOOKS:

1. Dale H. Besterfiled, Carol B. Michna, Glen H. Besterfield, Mary B.Sacre, Hemant Urdhwareshe and Rashmi Urdhwareshe, "Total Quality Management", Pearson Education Asia, Revised Third Edition, Indian Reprint, Sixth Impression, 2013.

REFERENCE BOOKS:

1.James R.Evans and William M.Lindsay, "The Management and Control of Quality", 8th Edition, First Indian Edition, Cengage Learning, 2012.

2.Janakiraman. BandGopal. R.K.,"Total Quality Management-Text and Cases", Prentice Hall (India) Pvt.Ltd.,2006.

3.Suganthi. Land Anand Samuel, "Total Quality Management", Prentice Hall (India) Pvt. Ltd., 2006.

4.ISO9001-2015standards

Note: The paper setter will set the paper as per the question paper template provided.

RAO-404 A	QUALITY AND RELIABILITY ENGINEERING						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	The purpose of this course is to provide students with an in-depth knowledge of quality and reliability. The course addresses the principles and techniques of Statistical Quality Control and their practical uses as well as give insight to modern reliability engineering tools.						
Course Outcomes: After studying the course, students will be able to:							
CO1	Students will be able to understand the concept of quality value and engineering and application of statistical methods for quality control. The student will also be able to solve the problems related with dispersion of data.						
CO2	Students will be able to understand different control charts and will solve the problems on control charts. They will also understand various sampling plans and design sampling plans.						
CO3	Students will be able to explain the loss function and tolerance design for online quality control. They will come to know the concept of reliability and will be able to understand the mathematical derivations of different failure rates.						
CO4	Students will be able to describe various hazard models and solve problems for finding reliability of complex systems.						

UNIT-I

Quality value and engineering: Quality systems, quality engineering in product design and production process, system design, parameter design, tolerance design, statistical methods for quality control and improvement, mean, median, mode, standard deviation, calculating area, Normal distribution tables, finding the Z score, Central limit theorem.

UNIT-II

Variation in process: Control charts for variables: X-bar and R charts, Control charts for attributes P, C and U-Chart, Establishing and interpreting control charts process capability, Quality rating, Short run SPC.

Acceptance sampling by variables and attributes, single, double, sequential and continuous sampling plans, design of various sampling plan.

UNIT–III

Loss function, tolerance design: N type, L type, S type; determination of tolerance for these types, online quality control – variable characteristics, attribute characteristics, parameter design.

Concept and definition of reliability: Reliability Parameters: Reliability as a function of time, failure rate as a function of time, Bath-tub curve, constant failure rate, increasing failure rate, mean time to failure (MTTF), MTTF as a function of failure rate, mean time between failure (MTBF), mean down time (MDT), maintainability & availability.

UNIT–IV

Brief discussion on hazard models: Constant hazard model, linearly increasing hazard model, nonlinear hazard model and Weilbull distribution, Advantages of weibull distribution, System reliability models: series system, parallel system, series-parallel system

Complex system: Reliability of series, parallel & standby systems & complex systems & reliability prediction and system effectiveness, reliability testing.

Text books:

1. Reliability Engineering, (3rdEdition) - LS Srinath, Affiliated East West Pvt Ltd, 1991..
2. Reliability Engineering- E.Bala Guruswamy, Tata McGraw Hill, 1994.
3. Statistical Quality Control- M. Mahajan, Dhanpat Rai & Co., 2018.
4. Statistical Process Control- Eugene Grant, Richard Leavenworth, McGraw Hill.

Reference books:

1. Introduction to Reliability Engineering- Lewis E. E., John Wiley & Sons - 1987
2. Reliability Based Design-Rao S. S., McGraw Hill - 1992
3. Practical Reliability Engineering- O'cconer P. D. T., John Wiley & Sons Ltd. - 2003
4. Statistical Quality Control-Eugene G. L., McGraw-Hill - 1996

RAO-406A	FIELD AND SERVICE ROBOTICS						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3 h**
Course Outcomes: After studying the course, students will be able to:							
CO 1	Explain the basic concepts of working of robot						
CO 2	Analyze the function of sensors in the robot						
CO 3	Write program to use a robot for a typical application						
CO 4	Use Robots in different applications						
CO5	Know about the humanoid robots						

UNIT-1

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-2

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

UNIT-3

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

FIELD ROBOTS-Ariel robots, Collision avoidance, Robots for agriculture, mining, exploration, underwater, civilian and military applications, nuclear applications, and Space applications.

UNIT-4

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, Case studies.

TEXT BOOKS:

1. Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza “Introduction to Autonomous Mobile Robots”, Bradford Company Scituate, USA, 2004
2. Riadh Siaer “The future of Humanoid Robots-Research and applications“, Intech Publications, 2012.

REFERENCE BOOKS:

1. Richard DK lafter, Thomas A Chmielewski, Michael Negin, "Robotics Engineering–An Integrated Approach", Eastern Economy Edition, Prentice Hall of India P Ltd., 2006.
2. Kelly, Alonzo;Iagnemma, Karl;Howard, Andrew, "Fieldand Service Robotics",Springer,2011

RAO-408A	ENTREPRENEURSHIP						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3 h**
Purpose							
Course Outcomes: Upon completion of the course, students will be able to gain knowledge and skills needed to run a business successfully.							
CO 1	Learners will pick up about Foundation of Entrepreneurship Development and its theories.						
CO 2	Learners will explore entrepreneurial skills and management function of a company with special reference to SME sector.						
CO 3	Learners will identify the type of entrepreneur and the steps involved in an entrepreneurial venture						
CO 4	Learners will understand various steps involved in starting a venture and to explore marketing methods & new trends in entrepreneurship.						

UNIT I

ENTREPRENEURSHIP- Entrepreneur, Types of Entrepreneurs, Difference between Entrepreneur and Intrapreneur, Entrepreneurship in Economic Growth, Factors Affecting Entrepreneurial Growth.

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

UNIT-2

BUSINESS- Small Enterprises – Definition, Classification – Characteristics, Ownership Structures – Project Formulation – Steps involved in setting up a Business – identifying, selecting a Good Business opportunity, Market Survey and Research, Techno Economic Feasibility Assessment – Preparation of Preliminary Project Reports – Project Appraisal – Sources of Information – Classification of Needs and Agencies.

UNIT-3

FINANCING AND ACCOUNTING- Need – Sources of Finance, Term Loans, Capital Structure, Financial Institution, Management of working Capital, Costing, Break Even Analysis, Taxation – Income Tax, Excise Duty – Sales Tax.

UNIT-4

SUPPORT TO ENTREPRENEURS- Sickness in small Business – Concept, Magnitude, Causes and Consequences, Corrective Measures - Business Incubators – Government Policy for Small Scale Enterprises – Growth Strategies in small industry – Expansion, Diversification, Joint Venture, Merger and Sub Contracting.

TEXT BOOKS:

1. Donald F Kuratko, "Entrepreneurship – Theory, Process and Practice", 9th Edition, Cengage Learning, 2014.
2. Khanka. S.S., "Entrepreneurial Development" S.Chand & Co. Ltd., Ram Nagar, New Delhi, 2013.

REFERENCE BOOKS:

3. EDII "Faulty and External Experts – A Hand Book for New Entrepreneurs Publishers: Entrepreneurship Development", Institute of India, Ahmadabad, 1986.
4. Hisrich R D, Peters M P, "Entrepreneurship" 8th Edition, Tata McGraw-Hill, 2013.
5. Mathew J Manimala, " Entrepreneurship theory at cross roads: paradigms and praxis" 2nd Edition Dream tech, 2005.
6. Rajeev Roy, "Entrepreneurship" 2nd Edition, Oxford University Press, 2011.

RAO-410A	COMPUTER INTEGRATED MANUFACTURING SYSTEMS						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3 h**
Course Outcomes: After studying the course, students will be able to:							
CO 1	Explain the basic concepts of CAD,CAM and computer integrated manufacturing systems						
CO 2	Summarize the production planning and control and computerized process planning						
CO 3	Differentiate the different coding systems used in group technology						
CO 4	Explain the concepts of flexible manufacturing system (FMS) and automated guided vehicle (AGV) system						
CO5	Classification of robots used in industrial applications						

UNIT-1

INTRODUCTION-Brief introduction to CAD and CAM – Manufacturing Planning, Manufacturing control- Introduction to CAD/CAM – Concurrent Engineering-CIM concepts – Computerized elements of CIM system –Types of production - Manufacturing models and Metrics – Mathematical models of Production Performance –Simple problems–Manufacturing Control–Simple Problems–Basic Elements of automated system–Levels of Automation–Lean Production and Just-In-Time Production.

UNIT-2

PRODUCTION PLANNING AND CONTROL AND COMPUTERISED PROCESS PLANNING- Process planning–Computer Aided Process Planning (CAPP)–Logical steps in Computer Aided Process Planning – Aggregate Production Planning and the Master Production Schedule – Material Requirement planning–Capacity Planning- Control Systems-Shop Floor Control-Inventory Control – Brief on Manufacturing Resource Planning-II (MRP-II) & Enterprise Resource Planning (ERP)-Simple Problems.

UNIT-3

CELLULAR MANUFACTURING-Group Technology (GT), Part Families–Parts Classification and coding–Simple Problems in Opitz Part Coding system–Production flow Analysis–Cellular Manufacturing–Composite part concept–Machine cell design and layout – Quantitative analysis in Cellular Manufacturing– Rank Order Clustering Method-Arranging Machines in a GT cell– Hollier Method–Simple Problems.

FLEXIBLE MANUFACTURING SYSTEM (FMS) AND AUTOMATED GUIDED VEHICLE SYSTEM (AGVS)-Types of Flexibility - FMS – FMS Components – FMS Application & Benefits – FMS Planning and Control – Quantitative analysis in FMS– Simple Problems. Automated Guided Vehicle System (AGVS) – AGVS Application – Vehicle Guidance technology – Vehicle Management &Safety.

UNIT-4

INDUSTRIAL ROBOTICS- Robot Anatomy and Related Attributes – Classification of Robots- Robot Control systems – End Effectors–Sensors in Robotics–Robot Accuracy and Repeatability-Industrial Robot Applications –Robot Part Programming–Robot Accuracy and Repeatability–Simple Problems

TEXT BOOKS:

1. Mikell.P.Groover "Automation, Production Systems and Computer Integrated Manufacturing", Prentice Hall of India, 2008.
2. Radhakrishnan P, Subramanyan S.and Raju V., "CAD/CAM/CIM", 2nd Edition, New Age International (P) Ltd, New Delhi, 2000.

REFERENCE BOOKS:

1. Gideon Halevi and Roland Weill, "Principles of Process Planning – A Logical Approach" Chapman & Hall, London, 1995.
2. Kant Vajpayee S, "Principles of Computer Integrated Manufacturing", Prentice Hall India.
3. Rao. P, N Tewari &T.K. Kundra, "Computer Aided Manufacturing", Tata McGraw HillPublishing Company, 2000.

RAO-412 A	INDUSTRIAL DRIVES FOR AUTOMATION						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	To understand & evaluate the knowledge of industrial drives for automation.						
Course Outcomes: After studying the course, students will be able to:							
CO1	Understanding principles of operation, types and applications of stepper motors						
CO2	Understanding principles of operation, types and applications of switched reluctance motors						
CO3	Evaluate knowledge in permanent magnet DC & synchronous motors						
CO4	understand the working and applications linear motors and servo motors						

UNIT-I

STEPPER MOTORS: Types - Constructional features – principle of operation – variable reluctance motor – single and Multistack configurations – Permanent Magnet Stepper motor – Hybrid stepper motor. Different modes of Excitation - theory of torque predictions – Drive systems and circuit for open loop and closed loop control of stepper motor.

UNIT-II

SWITCHED RELUCTANCE MOTORS: Constructional features – principle of operation –Torque Equation - Power Converters for SR Motor – Rotor Sensing Mechanism & Logic Controller – Sensorless Control of SR motor - Applications.

UNIT–III

PERMANENT MAGNET BRUSHLESS D.C. MOTORS: Principle of operation – Types – Magnetic circuit analysis – EMF and torque equations – Power controllers – Motor characteristics and control – Applications.

PERMANENT MAGNET SYNCHRONOUS MOTORS: Principle of operation, EMF, power input and torque expressions, Phasor diagram, Power Controllers, Torque speed characteristics, Self control, Vector control, Current control Schemes – Applications..

UNIT–IV

LINEAR MOTORS: Linear Induction motor (LIM) classification – construction – Principle of operation – Concept of current sheet – goodness factor – DC Linear motor (DCLM) types – circuit equation – DCLM control applications – Linear Synchronous motor(LSM) – Types–Applications Servomotors: Types – Constructional features, principle of operation - control applications.

TEXT BOOKS:

1. K. Venkataratnam," Special Electrical Machines", Universities Press (India) Private Limited, India,2009.
2. Kenjo, T and Naganori, S "Permanent Magnet and brushless DC motors", Clarendon Press,Oxford, 1989
3. Naser A and Boldea L,"Linear Electric Motors: Theory Design and Practical Applications", Prentice Hall Inc., New Jersey 1987.

REFERENCES:

1. Kenjo T, "Stepping Motors and their Microprocessor Controls", Clarendon Press London, 2003. 181
2. Miller T J E, "Brushless Permanent Magnet and Reluctance Motor Drives", Clarendon Press, Oxford, 1989.
3. Floyd E Saner, "Servo Motor Applications", Pittman USA, 1993.
4. WILLIAM H YEADON, ALAN W YEADON, Handbook of Small Electric Motors, McGraw Hill, INC, 2001

RAP-402 A	Artificial Intelligence for Robotics						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	To understand the basic concepts of artificial intelligence and to apply the acquired knowledge of AI in the robotics field.						
Course Outcomes: The student would be able to							
CO1	understand the basic concepts and techniques of Machine Learning						
CO2	understand regression methods, classification methods, clustering methods.						
CO3	apply Dimensionality reduction Techniques.						
CO4	apply the fundamentals of AI and expert systems and its application in Robotics						

UNIT-1

HISTORY OF AI- Introduction – History, Definition of AI, Emulation of human cognitive process, Intelligent agents – The concept of rationality, the nature of environments, the structure of agents.

UNIT-2

MACHINE LEARNING- Machine learning – Varieties of Machine learning – Learning Input- Output functions: Types of learning – Input Vectors – Outputs – Training regimes – Noise – Performance Evaluation.

Foundations of Supervised Learning: Decision trees and Inductive bias – Geometry and nearest neighbors – Logistic regression – Perceptron – Binary classification.

UNIT-3

ADVANCED SUPERVISED LEARNING- Linear models and gradient descent – Support Vector machines – Naive Bayes models and probabilistic modeling – Model selection and feature selection – Model Complexity and Regularization.

UNIT-4

UNSUPERVISED LEARNING-Curse of dimensionality, Dimensionality Reduction, PCA, Clustering – K-means – Expectation Maximization Algorithm – Mixtures of latent variable models – Supervised learning after clustering – Hierarchical clustering – Case studies.

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

TEXT BOOKS:

1. Russell Stuart, Norvig Peter, "Artificial Intelligence Modern Approach", Pearson Education series in AI, 3rd Edition, 2010.
2. Artificial Intelligence for Robotics Build intelligent robots that perform human tasks using AI Techniques, Francis X. Govers, August 2018.
3. Peter Flach, Machine Learning: The Art and Science of Algorithms that make sense of data, Tom Mitchell, Machine Learning ', McGraw Hill, 2015.

REFERENCE BOOKS:

1.Donald. A. Waterman, "A guide to Expert Systems", Pearson, 2002

2.Dan. W. Patterson, "Introduction to Artificial Intelligence and Expert Systems", PHI Learning,2009.

3.David MacKay, Information Theory, Inference and Learning Algorithms', Cambridge, 2003.

4.Ethem Alpaydin,'Introduction to Machine Learning', The MIT Press, 2004

5.Hal Daume III,A course in Machine Learning', Todo, 2015.

Note: The paper setter will set the paper as per the question paper template provided.

RAP-404 A	MODREN ROBOTICS						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose							
Course Outcomes: The student would be able							
CO1	Familiarize with anatomy, specifications and types of Robots						
CO2	Obtain forward and inverse kinematic models of robotic manipulators						
CO3	Plan trajectories in joint space & Cartesian space and avoid obstacles while robots are in motion						
CO4	Familiarize with different types of mobile robots, kinematic models, motion control and sensors for mobile robots						

UNIT-1

Configuration Space- Degrees of freedom, Configuration Space- topology and representation, configuration and velocity constraints, task space and workspace.

Rigid-Body Motions- Rigid-Body Motions in the Plane, Rotations and Angular Velocities, Rigid-Body Motions and Twists, wrenches

UNIT-2

Forward Kinematics- Product of Exponentials Formula, The Universal Robot Description Format

Velocity Kinematics and Statics - Manipulator Jacobian, Statics of Open Chains, Singularity Analysis, Manipulability

Inverse Kinematics- Analytic Inverse Kinematics, Numerical Inverse Kinematics, Inverse Velocity Kinematics

UNIT-3

Kinematics of Closed Chains - Inverse and Forward Kinematics, Differential Kinematics, Singularities

Dynamics of Open Chains – Lagrangian Formulation, Dynamics of Single Rigid Body, Newton-Euler Inverse Dynamics, Dynamic Equations in Closed Form, Forward Dynamics of Open Chain, Dynamics in Task Space, Constrained Dynamics, Robot Dynamics in URDF, Actuation, Gearing and Friction

Trajectory Generation – Point-to-point & polynomial via point trajectories, time-optimal time scaling

UNIT-4

Motion Planning- overview, foundations, complete path planners, grid methods, sampling methods, virtual potential fields, nonlinear optimization, smoothing

Robot Control- overview, error dynamics, motion control with velocity inputs, motion control with torque & force inputs, force control, hybrid motion-force control, impedance control, low level joint control

Contact kinematics, types of wheeled mobile robots, omnidirectional & nonholonomic wheeled mobile robots.

TEXT BOOKS:

1. Kevin M. Lynch and Frank C. Park, “Modern Robotics : Mechanics, Planning, and Control”, Cambridge University Press, 2017.

REFERENCE BOOKS:

1.R. Bellman and S. Dreyfus. “Applied Dynamic Programming”, Princeton University Press, Princeton, NJ, 1962.

2.O. Bottema and B. Roth. “Theoretical Kinematics. Dover Publications”, 1990

3.S. Chiaverini, G. Oriolo, and A. A. Maciejewski. Redundant robots. In B. Siciliano and O. Khatib, editors, “Handbook of Robotics”, Second Edition, Springer-Verlag, 2016

4.J. Craig. “Introduction to Robotics: Mechanics and Control”, third edition, Prentice-Hall, Upper Saddle River, NJ, 2004.

Note: The paper setter will set the paper as per the question paper template provided.

RAP- 406A	MAINTENANCE AND SAFETY ENGINEERING						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	. The purpose of this course is to develop an understanding of maintenance and safety engineering among students.						
Course Outcomes: After studying the course, students will be able to:							
CO1	Students will be able to understand about types and elements of maintenance.						
CO2	Students will be able to understand about total productive maintenance and its implementation.						
CO3	Students will be able to understand about safety system analysis, hazard analysis and fire protection system.						
CO4	Students will be able to understand about safety in machine operations and safety and law.						

UNIT-I

MAINTENANCE- Types, breakdown, preventive, predictive, TPM; elements of preventive maintenance–checklist, schedule, procedure.

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 II

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

UNIT III

HAZARDANALYSIS: General hazard analysis: electrical, physical and chemical hazard, detailed hazard analysis. Cost effectiveness in hazard elimination. Logical analysis: map method, tabular method, fault tree analysis and hazop studies. FIRE PROTECTION SYSTEM: Chemistry of fire, water sprinkler, fire hydrant, alarm and detection system. Suppression system: CO2 system, foam system, Dry Chemical Powder(DCP)system, halon system, portable extinguisher.

UNIT IV

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. SAFETY AND LAW: Provisions in factory act for safety, explosive act, workmen compensation act, compensation calculation. Boiler act and pollution control act

TEXT BOOKS:

1. DVS Murthy, Transducers and Instrumentation, PHI 2nd Edition 2013
2. D Patranabis, Sensors and Transducers, PHI 2nd Edition 2013.
3. S. Gupta, J.P. Gupta / PC interfacing for Data Acquisition & Process Control, 2nd ED / Instrument Society of America, 1994.
4. Gary Johnson / Lab VIEW Graphical Programing II Edition / McGraw Hill 1997.

REFERENCE BOOKS:

1. Arun K. Ghosh, Introduction to measurements and Instrumentation, PHI, 4th Edition 2012.
2. A.D. Helfrick and W.D. cooper,Modern Electronic Instrumentation & Measurement Techniques, PHI – 2001
3. Hermann K.P. Neubert, "Instrument Transducers" 2nd Edition 2012, Oxford University Press.

Note: The paper setter will set the paper as per the question paper template provided.

RAP-408A	Object Oriented Programming and Data Structures						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time**
3	**0**	**0**	**3.0**	**75**	**25**	**100**	**3 Hour**
Purpose	To introduce the principles and paradigms of Object Oriented Programming, along with Data Structures for designing and implementing the software systems logically and physically.						
Course Outcomes (CO)							
CO 1	To introduce the basic concepts of object-oriented programming languages and their representation.						
CO 2	To explore accessing private members of a class and the behavior of inheritance, along with its implementation, as well as delving into polymorphism, interface design, and operator overloading.						
CO 3	To introduce the basic concepts of data structures, basic data types, searching, and sorting based on array data types, as well as structured data types like stacks and queues, along with their basic operations' implementations.						
CO 4	To introduce the dynamic implementation of linked lists and the concepts of trees and graphs, along with the implementation of traversal algorithms						

Unit-1

Introduction to C++, Illustrative Simple C++ Programs. Header Files, Namespaces, Application of object oriented programming.

Object Oriented Concepts, Introduction to Objects and Object Oriented Programming, Encapsulation, Polymorphism, Overloading, Inheritance, Abstract Classes, Class Scope and Accessing Class Members, Class Member. Friend Function and Friend Classes, Constructors, parameter Constructors and Copy Constructors, Deconstructor.

Unit-2

Introduction of inheritance, Types of Inheritance, Access specifier (public/ protected/ private), Overriding Base Class Members in a Derived Class, effect of Constructors and Deconstructors of Base Class in Derived Classes.

Polymorphism, Pointer to Derived class, Virtual Functions, Pure Virtual Function, Abstract Base Classes, Static and Dynamic Binding, Virtual Deconstructors. Fundamentals of Operator Overloading, Rules for Operators Overloading.

Unit-3

Introduction to Data Structures, Data Types, Built in and User Defined Data Structures, Applications of Data Structure, Algorithm Analysis, Worst, Best and Average Case Analysis, Notations of Space and Time Complexity. Arrays, One Dimensional Arrays, Two Dimensional Arrays and Multi-Dimensional Arrays, Searching from array using Linear and Binary Searching Algorithm, Sorting of array using Selection,Insertion, Bubble algorithm.

Stacks: Definition, Implementation of Stacks and Its Operations, Evaluation of Infix, prefix and Postfix Expression, Inter-conversion of Infix, Prefix and Post-Fix Expression. Queues: Definition, Sequential Implementation of Linear Queues and Its Operations, Circular Queue and Its Implementation, Priority Queues and Its Implementation, Applications of queues.

Unit-4

Linked Lists: Need of Dynamic Data Structures, Single Link List and Its Dynamic Implementation, Traversing, Insertion, Deletion Operations on Single Link Lists.

Trees: Definition, Basic Terminology, Binary Tree, External and Internal Nodes, Static and Dynamic Implementation of a Binary Tree, Primitive Operations on Binary Trees.

Graphs: Basic Terminology, Definition of Undirected and Directed Graphs, Memory Representation of Graphs, Minimum-Spanning Trees, Warshal Algorithm, Graph Traversals Algorithms: Breadth First and Depth First.

Suggested Books:

- The complete reference C ++ by Herbert shieldt Tata McGraw Hill.
- Object Oriented Programming in Turbo C++ by Robert Lafore, 1994, The WAITE Group Press.
- Theory and Problems of Data Structures by Jr. Symour Lipschetz, Schaum's outline, TMH.
- Data Structures and Algorithms by PAI, TMH.
- Fundamentals of Data structures by Ellis Horowitz and Sartaj Sahni, Pub, 1983, AW.
- Data Structures and Algorithms by A.V. Aho, J.E. Hopcroft and T.D. Ullman, Original edition, Addison-Wesley, 1999, Low Priced Edition.
- Data Structures and Program Design in C by Robert Kruse, PHI,
- Shukla, Data Structures using C++, Wiley India
- Introduction to Computers Science -An Algorithms Approach, Jean Paul Tremblay, Richard B. Bunt, 2002, T.M.H.

RAP-410 A	TOTALLY INTEGRATED AUTOMATION						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	To apply the knowledge of PLC & SCADA to the design and develop automatic control system.						
Course Outcomes: After studying the course, students will be able							
CO1	To gain knowledge in automation in industries and various electrical and electronic programmable automations and their applications.						
CO2	To know about the basic in SCADA and DCS systems.						
CO3	To gain knowledge in communication protocols in an integrated system.						
CO4	To know about the advanced in automation industries						

UNIT-I

TOTALLY INTEGRATED AUTOMATION: Need for TIA - TIA Architecture - Components of TIA systems - Selection of TIA Components – Programmable Automation Controllers (PAC) – Vertical Integration structure.

UNIT-II

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA): Overview – Developer and runtime packages – Architecture – Tools – Tags – Graphics - Alarm logging – Tag logging – Trends – History – Report generation, VB & C Scripts for SCADA application.
COMMUNICATION PROTOCOLS OF SCADA: Proprietary and open Protocols – OLE/OPC – DDE – Server/Client Configuration – Messaging – Recipe – User administration – Interfacing of SCADA with PLC, drive, and other field device

UNIT–III

DISTRIBUTED CONTROL SYSTEMS (DCS): DCS – architecture – local control unit- programming language – communication facilities – operator interface – engineering interfaces

UNIT–IV

INDUSTRIAL PLANT DESIGN: Design criteria – Process sequencing - Plant layout modelling – Selection of industrial power and automation cables,
Overview of plant simulation software. Case Studies: Case studies of Machine automation, Process automation.

TEXT BOOKS:

1. David Bailey, Edwin Wright, ―Practical SCADA for industry, Newnes, Burlington, 2003.

2. Gordon Clarke, Deon Reynders, Edwin Wright, ―Practical Modern SCADA Protocols: DNP3, 60870.5 and Related systems‖, Newnes Publishing, 2004.

Note: The paper setter will set the paper as per the question paper template provided.

RAP-412A	FLEXIBLE MANUFACTURING SYSTEMS						
Lecture	**Tutorial**	**Practical**	**Credit**	**Major Test**	**Minor Test**	**Total**	**Time (Hrs)**
3	**0**	**0**	**3**	**75**	**25**	**100**	**3**
Purpose	The purpose of this course is to develop an understanding of basics of flexible manufacturing systems.						
Course Outcomes: After studying the course, students will be able to:							
CO1	Students will be able to understand about types, economics, development, implementation and layouts of FMS						
CO2	Students will be able to understand about basics of automated material handling and storage						
CO3	Students will be able to understand about basics of computer control, software, simulation and data base of FMS						
CO4	Students will be able to understand about basics of scheduling of FMS						

UNIT-I

FMS Introduction: Definition of an FMS-need for FMS, types and configuration, types of flexibilities and performance measures. Economic justification of FMS. Development and implementation of FMS- planning phases, integration, system configuration, FMS layouts, simulation.

UNIT-II

Automated Material Handling and Storage: Functions – types - analysis of material handling systems, primary and secondary material handling systems-conveyors, Automated Guided Vehicles-working principle, types, traffic control of AGVs. Role of robots in material handling. Automated storage systems- storage system performance – AS/RS-carousel storage system, WIP storage systems, interfacing handling and storage with manufacturing.

UNIT–III

Computer Control of FMS: Planning, scheduling and computer control of FMS, Hierarchy of computer control, supervisory computer. DNC system- communication between DNC computer and machine control unit, features of DNC systems.

Computer Software, Simulation and Data Base of FMS: System issues, types of software – specification and selection-trends-application of simulation and its software, Manufacturing Data systems- planning FMS data base. Modeling of FMS- analytical, heuristics, queuing, simulation and petrinets modeling techniques.

UNIT–IV

Scheduling of FMS: Scheduling of operations on a single machine- two machine flow shop scheduling, two machine job shop scheduling, - three machine flow shop scheduling- scheduling 'n' operations on 'n' machines, knowledge-based scheduling, scheduling rules, tool management of FMS, material handling system schedule.

Reference Books:

1. Jha. N.K., "Hand Book of Flexible Manufacturing Systems", Academic Press Inc,1991
2. Raouf, A. and Ben-Daya, M., Editors, "Flexible manufacturing systems: recent development", Elsevier Science, 1995.
3. Parish.D.J., "Flexible Manufacturing", Butter worth-Heinemann Ltd,1990.
4. Groover. M. P., "Automation production systems and computer integrated manufacturing", Prentice hall of India pvt.Ltd, 1989.

5. Taiichi Ohno, “Toyota production system: beyond large-scale production” Productivity Press (India) Pvt. Ltd. 1992.
6. Buffa .E.S. and Sarin, “Modern Production and Operations Management”, Wiley Eastern, 1987. 7. Radhakrishnan P. and Subramanyan S., “CAD/CAM/CIM”, Wiley Eastern Ltd.,New Age International Ltd., 1994.