M. Tech.

in

INDUSTRIAL AUTOMATION

CURRICULUM

(for students admitted in the year 2022)

DEPARTMENT OF
INSTRUMENTATION AND CONTROL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI – 620 015
TAMIL NADU, INDIA

INSTITUTE VISION

- To be a university globally trusted for technical excellence where learning and research integrate to sustainsociety and industry.

INSTITUTE MISSION

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia andindustry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically

DEPARTMENT VISION

- To be a world class centre of excellence in Instrumentation and Control Engineering.

DEPARTMENT MISSION

- To inspire the students to realize their aspiration and potential through quality education inInstrumentation and Control Engineering.
- To enhance knowledge, create passion for learning, foster innovation and nurture talents towardsserving the society and the country.
- To encourage faculty and students to keep in pace with the latest technological developments and topursue research in those areas.
- To enable the students to engage themselves in entrepreneurship and product development for thebenefit of the global community.

Program Educational Objective (PEOs)

1. To provide fundamental and advanced knowledge in order to produce competent, innovative automation engineers.
2. To use graduate engineering knowledge in Instrumentation and Control and Mechanical to design engineering systems for industrial automation.
3. To promote independent and collaborative work, while demonstrate the professional and ethical responsibility.
4. To promote development of intellectual property by automation engineers.
5. To produce post graduate automation engineers capable of taking up research on the emerging technology and have lifelong learning.

Program Outcome

The students will be able to

1. Independently carry out development work to solve practical problems in Industrial Automation.
2. To write and present a substantial technical report/document in Industrial Automation.
3. To demonstrate a degree of mastery in the area of Industrial Automation.

CURRICULUM

The total minimum credits for completing the M. Tech. programme in IndustrialAutomation is 64.

SEMESTER I

Sl. No.	Course Code	Course Title	Credits
1.	MA 623	Applied Mathematics	3
2.	IC 601	Measurements in Manufacturing and Process Industries	3
3.	IC 603	Industrial Automation Systems	3
4.		ELECTIVE 1	3
5.		ELECTIVE 2	3
6.		ELECTIVE 3	3
7.	IC 607	Process Instrumentation and Automation Laboratory	2
Total			**20**

SEMESTER II

Sl. No.	Course Code	Course Title	Credits
1	IC 602	Industrial and Data Communications	3
2	IC 604	Electric Drives and Control	3
3	IC 606	Robotics in Industrial Automation	3
4		ELECTIVE 4	3
5		ELECTIVE 5	3
6		ELECTIVE 6	3
7	IC 608	AI and Robotics Laboratory	2
Total			**20**

SEMESTER III

Course Code	Course Title	Credits
IC 609	PROJECT WORK - PHASE I	12
	Total	**12**

SEMESTER IV

Course Code	Course Title	Credits
IC 610	PROJECT WORK - PHASE II	12
	Total	**12**

LIST OF ELECTIVES - SEMESTER I

Sl. No.	Course Code	Course Title	Credits
1.	IC 611	Artificial Intelligence in Industrial Automation	3
2.	IC 613	Modeling, Simulation and Analysis of Manufacturing Systems	3
3.	IC 615	Embedded Systems	3
4.	IC 617	Intelligent Transportation Systems	3
5.	IC 619	Fluid Power Systems	3
6.	IC 621	Advanced Control System	3
7.	IC 623	System Identification	3
8.	IC 625	Building and Infrastructure Systems and Automation	3

LIST OF ELECTIVES - SEMESTER II

Sl. No.	Course Code	Course Title	Credits
1.	IC 612	Industrial Internet of Things	3
2.	IC 614	Computer Vision and Image Processing	3
3.	IC 616	Predictive Analytics	3
4.	IC 618	Wireless Sensor Networks	3
5.	IC 620	Augmented Reality	3
6.	IC 622	Networked Control System	3
7.	IC 624	Cyber Security in Industrial Automation	3
8.	IC 626	Rapid Prototyping	3
9.	IC 628	Optimization Techniques	3

Course Code	**:**	**MA 623**
Course Title	**:**	**Applied Mathematics**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objectives

1. To learn the concepts of probability and statistics to industrial automation engineering problems.
2. Familiar with reliability engineering theory in determining the reliability of the systems.
3. To predict the relationship between parameters through correlation and regression analysis.
4. Compute the reliability of the systems.

Course Content

Random variable – Two dimensional random variables – Standard probability distributions – Binomial, Poisson and Normal distributions - Moment generating function.

Special distributions – Uniform, Geometric, Exponential, Gamma, Weibull and Beta distributions –Mean, Variance, Raw moments from moment generating functions of respective distributions.

Sampling distributions – Confidence interval estimation of population parameters – Testing of hypotheses – Large sample tests for mean and proportion – t-test, F-test and Chi-square test. Case studies pertaining to engineering.

Curve fitting - Method of least squares - Regression and correlation – Rank correlation – Multiple and partial correlation – Analysis of variance - One way and two-way classifications Case studies pertaining to engineering.

Introduction to Multivariate statistical analysis – Multiple linear regression-Multiple logistic regression – Multivariate analysis of variance (MANOVA) – Introduction to Factor analysis, Cluster analysis, Principal components analysis (PCA).

Text Books

1. *Gupta S.C. and Kapoor V.K., "Fundamentals of Mathematical Statistics", 11th Edition Sultan Chand, New Delhi, 2018.*
2. *Trivedi K.S., "Probability and Statistics with Reliability and Queuing and Computer Science Applications", 2nd Edition, Wiley, 2008.*

Reference Books

1. *Spiegel, Murray, "Probability and Statistics", Schaum's series, McGraw Hill, 2017.*
2. *Spiegel, Murray R., "Statistics", Schaum's series, 2008.*
3. *Bowker and Liberman, "Engineering Statistics", 2nd Edition, Prentice-Hall, 1972.*

Course Outcomes

On completion of this course, the students will be able to

1. Apply standard and special probability distributions to automation engineering problems.
2. Indicate data pictorially and numerically and analyze it.
3. Employ sampling distributions in testing various hypotheses.
4. Use t-test, F-test and Chi-square test in determining the validity of data.

Course Code	**:**	**IC 601**
Course Title	**:**	**Measurement in Manufacturing and Process Industries**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objectives

1. To expose the students to the importance of measurements in manufacturing and processindustries.
2. To expose the students to various measurement techniques used for the measurement ofphysical variables in manufacturing industries.
3. To expose the students to various measurement techniques used for the measurement ofphysical variables in process industries.
4. To make the students knowledgeable in the design, installation and troubleshooting of theinstruments used in manufacturing and process instruments.

Course Content

Transducers: Resistance, capacitance, inductance type, piezoelectric and photoelectric transducers- signal conditioning circuits, and its static and dynamic characteristics and its applications.

Calibration and ISA standards. Proximity Sensors: Inductive, Capacity, Magnetic, Ultrasonic, IR, Light detection and ranging (Lidar) sensors, applications of proximity sensors.

Review of temperature measuring instruments. Transmitters: two wire and four wire, open loop and closed loop transmitters, smart, intelligent and wireless transmitters, transmitter design using analog circuits and ICs.

Flow measurement: Differential pressure and variable area flow meters, Electromagnetic flow meters. Hot wire anemometer, laser Doppler anemometer, ultrasonic and measurement of mass flow rate. Level measurement - Differential pressure level detectors, Capacitance level sensor, Ultrasoniclevel detectors and Radar level transmitters and gauges.

EMI and EMC: Introduction, interference coupling mechanism, basics of circuit layout and grounding, concepts of interfaces, filtering and shielding.
Safety: Introduction, electrical hazards, hazardous areas and classification, non-hazardous areas, enclosures-NEMA types, fuses and circuit breakers. Protection methods: Purging, explosion proofing and intrinsic safety.

Application of sensors in automation: Assembly shop in automobile manufacturing, Autonomous vehicle, oil and gas pipeline monitoring, water distribution system, intelligent transportation systems, monitoring of food.

Quality and safety, sorting, counting and bottle filling system, construction and management, building and home, rail, and filling of gas cylinders.

Text Books

1. *Ernest. O. Doebelin and Dhanesh.N.Manik, "Measurement Systems, McGraw Hill Education, 6th Edition, 2011.*
2. *Thomas G. Beckwith, Roy D. Marangoni, Lienhard, "Mechanical Measurements", Pearson Education India, 6th Edition, 2013.*
3. *Patranabis D, "Principles of Industrial Instrumentation", Tata McGraw Hill, 3rd Edition, 2010.*

Reference Books

1. *B.G.Liptak, "Process Measurement and Analysis", CRC Press, 4th Edition, 2003.*
2. *B.E.Noltingk, "Instrumentation Reference Book", Butterworth Heinemann, 2nd Edition, 1995.*
3. *Douglas M. Considine, "Process / Industrial Instruments & Controls Handbook", McGraw Hill, Singapore, 5th Edition, 1999.*
4. *Andrew W.G, "Applied Instrumentation in Process Industries – A survey", Vol I &Vol II, Gulf Publishing Company, Houston, 2001*
5. *Spitzer D. W., "Industrial Flow measurement", ISA press, 3rd Edition, 2005.*
6. *Tony. R. Kuphaldt, "Lessons in Industrial Instrumentation", Version 2.02, April 2014.*
7. *Lawrence D. Goettsche, "Maintenance of Instruments and Systems", International Society of Automation, 2nd Edition, 2005.*
8. *Norman A. Anderson, "Instrumentation for Process Measurement and Control", CRC Group, Taylor and Francis Group, 3rd Edition, 2010.*
9. *James W. Dally, William F. Riley, Kenneth G. McConnell "Instrumentation for Engineering Measurements", Wiley India Private Limited, 2nd Edition, 2010.*
10. *Alessandro Brunelli, "Calibration Handbook of Measuring Instruments", ISA, 2017*
11. *Mohit Pandey, Shreyansh Tatiya, Shantanu Bhattacharya, Shailendra Singh, "Sensorsfor Automotive and Aerospace Applications", Springer Singapore, 2019*

Course Outcomes

On completion of this course, the students will be able to

1. Study the characteristics and specification of instruments.
2. Understand the sensors and transducers used in manufacturing industries like displacement,velocity, acceleration, force, torque and load.
3. Gain knowledge of different temperature, pressure, flow and level measurement techniques used in process industries.
4. Grasp the industrial safety aspects.

Course Code	**:**	**IC 603**
Course Title	**:**	**Industrial Automation Systems**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objectives

1. To present the importance of automation in manufacturing and process industries.
2. To impart the role of PLC in industrial automation.
3. To expose the various automation techniques employed in process control.
4. To impart knowledge on different communication protocols used in process automation.

Course Content

Automation in Manufacturing & Process Industries:
Introduction: Automation in manufacturing system, Principles and strategies of automation, Basic elements of an automated system, Advanced automation functions, Levels of automations,Various Industrial Revolutions, Digitalization and the Networked Economy, Drivers, Enablers, Compelling Forces and Challenges for Industry 4.0.

Technologies enabling Industry 4.0: Introduction and overview of Internet of Things, cloud computing, cyber-physical systems.
Automated flow lines and transfer mechanisms: Analysis of transfer lines without storage, automated flow lines with storage buffers
Introduction to Smart Manufacturing: smart devices and products, smart logistics, smart cities, predictive analytics

Programmable Logic Controller (PLC): Introduction to PLC, History of PLC, Architecture of PLC, CPU IO Modules Power Supply and Communications, Input and Output Devices, Need of PLC forIndustrial Automation, Types of PLC Models.
Introduction to PLC Programming: Types of Programming Languages, Ladder logic diagram, Examine On/OFF, timer, counter, data manipulation and other higher-level programming instruction with case studies.

Overview of material handling systems: Types of material handling equipment, Design of the system, Conveyor system, Automated guided vehicle system.
Automated Manufacturing Systems: Components, Classification and overview of manufacturing systems, Cellular manufacturing, Flexible manufacturing system (FMS).

SCADA Systems: Introduction, definition and history of SCADA, typical SCADA System Architecture, Communication requirements, Desirable properties of SCADA system, Features, advantages, disadvantages and applications of SCADA.

SCADA Architecture: First Generation-Monolithic, Second Generation-Distributed, Third Generation-Networked Architecture, SCADA systems in operation and case studies.

Distributed control systems (DCS): Introduction - Local Control Unit (LCU) architecture, LCU Process Interfacing Issues, Block diagram and Overview of different LCU security design approaches, Networking of DCS. Information gathering, Real-time analysis of data stream from DCS, Historian, Integration of business inputs with process data, Leveraging remote terminal unit (RTU).

Process Safety Automation: Levels of process safety through use of PLCs, Integrating Process safety PLC and DCS, Application of international standards in process safety control.

Text Books

1. *M.P.Groover, "Automation, Production Systems and Computer IntegratedManufacturing", 5 th Edition, Pearson Education, 2009.*
2. *John W. Webb and Ronald A. Reis, "Programmable Logic Controllers: Principles andApplications", 5th Edition, Prentice Hall Inc., New Jersey, 2003.*
3. *Krishna Kant, "Computer - Based Industrial Control", 2nd Edition, Prentice Hall, New Delhi, 2011.*
4. *Frank D. Petruzella, "Programmable Logic Controllers", 5th Edition, McGraw-Hill,New York, 2016.*
5. *Ronald L Krutz, "Securing SCADA System", First Edition, Wiley Publication, 2005*

Reference Books

1. *Curtis D. Johnson, "Process Control Instrumentation Technology", 8th Edition,Pearson New International, 2013.*
2. *Lukas M.P, "Distributed Control Systems", Van Nostrand Reinhold Co., New York,1986.*
3. *N. Viswanandham, Y. Narahari, "Performance Modeling of Automated Manufacturing Systems", 1st Edition, 2009.*
4. https://nptel.ac.in/syllabus/108108098/
5. *Smith Carlos and Corripio, "Principles and Practice of Automatic Process Control",3rd Edition, John Wiley & Sons, 2006.*

Course Outcomes

On completion of this course, the students will be able to

1. Familiar with various automation technologies used in manufacturing and process industries.
2. Apply various programming techniques for manufacturing industry automation.
3. Understand various automation techniques such as DCS and SCADA for process industryautomation.
4. Familiar with various process safety automation and I4 standards.

Course Code	**:**	**IC 607**
Course Title	**:**	**Process Instrumentation and Automation Laboratory**
Number of Credits	**:**	**2**
Course Type	**:**	**Laboratory**

Course Learning Objectives

1. Impart knowledge in transmitter design.
2. Exposure to different PLC programming languages.
3. Able to provide adequate knowledge in SCADA and DCS.
4. Study of HART and Field bus protocol.

List of Experiments

1. Design and development of two wire temperature Transmitter.
2. Design and development of IoT based transmitter.
3. Design and implementation of feedback and cascade control schemes on theExperimental set up.
4. Design and implementation of feed forward and ratio control schemes on theExperimental set up.
5. Development of combinational and sequential logic application using minimum PLClanguages.
6. Development of Ladder logic Program for control of processes.
7. Development of SCADA for a control of processes.
8. Study of HART and Field bus protocol.
9. P&I diagram development using simulation software for complex processes.
10. Study of Distributed Control System and different instruction sets.
11. Development of Cascade, ratio and feedback controller using DCS simulation software.
12. Development of HMI and annunciator circuits using DCS simulation software.

Course Outcomes

Upon completion of the course students will be able to

1. Gain confidence in development of conventional/ wireless IoT based transmitter suitedfor real time processes.
2. Get exposure in design of different controller suitable for real time processes.
3. Adequate programming skills using PLC, DCS and SCADA.
4. Gain knowledge on Ladder Logic programming.

Course Code	**:**	**IC 602**
Course Title	**:**	**Industrial and Data Communications**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objectives

1. To expose the students to Communication systems emerged in the field of industrialautomation.
2. To learn the protocols used for data communication.
3. to test, build, wire and troubleshoot the different types of industrial data communicationcircuits used for instrumentation
4. To expose the students to more advanced, precise and complex instrumentations whichare being employed in the automation industry

Course Content

Interface: Introduction, Principles of interface, serial interface and its standards, Parallel interfaces and buses, OSI Standard – TCP/IP protocol.

Fieldbus: Use of fieldbuses in industrial plants, function blocks, international standards, performance, use of Ethernet networks, fieldbus advantages and disadvantages, Fieldbus design, installation, economics and documentation.

Instrumentation network design and upgrade*:* Instrumentation design goals, cost optimal and accurate sensor networks, Global system architectures, advantages and limitations of open networks,HART network, Foundation fieldbus network, control area network (CAN) and MQTT protocol, Open Platform Communications Unified Architecture (OPC-UA).

HART and MODBUS: Concept of Highway Addressable Remote Transducer (HART), HART andsmart Instrumentation, HART protocol, HART Physical layer, HART Data link layer, HART benefits, Troubleshooting of HART, Overview of Modbus protocol, Modbus protocol structure.

PROFIBUS-PA*:* Basics, architecture, model, network design and system configuration. Designing PROFIBUS-PA and Foundation Fieldbus segments: general considerations, network design.

CAN Bus*:* Introduction to CAN, messages, physical layers, connectors, Bit timing, Error handling, higher layer protocols, automotive applications.

MQTT*:* Introduction, public and subscribe basics, client, broker and connection establishment, Quality of Service, MQTT over web-sockets. Applications of MQTT: M2M communication, IoT.

Text Books

1. *B.G. Liptak, "Process software and digital networks", 3rd Edition, CRC press, Florida, 2003.*
2. *Michael A. Miller, "Introduction to Data and Network Communication", 1st edition Delmar Cengage Learning, 1992.*
3. *Forouzen, Data Communication and Networking, second Edition, MHE, 2017.*

Reference Books

1. *Stallings Williams, "Data and Computer Communication", Fourth Edition, PHI Learning, New Delhi, 1994.*
2. *Tannebaum Andrew S, Wetherall David J, "Computer Networks Pearson", 5th Edition, Prentice Hall, USA, 2011.*

Course Outcomes

On completion of this course, the students will be able to

1. Understand the concepts required for building industrial systems.
2. Explain various methods and protocols used for data communication.
3. Troubleshoot problems in hardware/software employed in data communication circuit.
4. Install various types of network devices and another network hardware for field and ProfiBUS.

Course Code	**:**	**IC 604**
Course Title	**:**	**Electric Drives and Control**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objectives

1. To introduce basic concepts of load and drive interaction, speed control concepts of acand dc drives, speed reversal, regenerative braking aspects.
2. To introduce to the students on the concept of employing power convertors for thedesign of electric drives.
3. To impart knowledge on the analysis of electric drive system dynamics.
4. To impart knowledge on the design methodology and development of control methodsfor electric drive systems.

Course Content:

Components of electrical drives system – electric machines, power converter, controllers – dynamics of electric drive – types of load – shaft-load coupling systems – four quadrant operation of a motor – stability of power electronic drive.

DC motor drives – conventional methods of speed control, single phase and three phase converter fed DC motor drive. Four quadrant operation.

Chopper fed drives, input filter design. Braking and speed reversal of DC motor drives using choppers, multiphase choppers. PV fed DC drives.

Induction motor drives – conventional methods of speed control – solid state controllers for stator voltage control – soft starting of induction motors, Rotor side speed control of wound rotor induction motors. Voltage source and Current source inverter fed induction motor drives – d-q axis modeling and vector control.

Synchronous motor drives – speed control of synchronous motors – field-oriented control – load commutated inverter drives – switched reluctance motor drives and permanent magnet motor drives. Sensor less speed control. Case studies on drives and applications.

Text Books:

1. *Richard Crowder, "Electric Drives and Electromechanical Systems", 2nd Edition,Elsevier, 2019*
2. *Ion Boldea, S. A. Nasar," Electrical Drives", 3rd Edition, CRC Press - 2016.*
3. *R. Krishnan, "Electrical Motor Drives", PHI - 2001.*
4. *G. K. Dubey, "Fundamentals of Electrical Drives", 2nd Edition, Narosa -2009.*
5. *M. A. El-Sharkawi, "Fundamentals of Electrical Drives", Cengage Learning, 2nd edition, 2000.*

Reference Books:

1. *Vedam Subrahmaniam," Electric Drives", 2nd Edition, TMH - 2017.*
2. *Ramu Krishnan," Permanent Magnet Synchronous and Brushless DC Motor Drives",CRC Press, 2017.*
3. *W. Leohnard, "Control of Electric Drives", 3rd Edition, Springer - 2001.*
4. *Bimal K Bose, "Modern Power Electronics and AC Drives", Prentice Hall, 1^{st}edition, 2002.*

Course Outcomes:

On completion of this course, the students will be able to,

1. Design suitable power electronic circuit for an electric drive system and analyze itssteady state stability.
2. Select appropriate control method for the electric drives.
3. Select a suitable electric drive for a particular industrial application.
4. Design and implement a prototype drive system.

Course Code	**:**	**IC 606**
Course Title	**:**	**Robotics in Industrial Automation**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objectives

1. To introduce the basic concepts, parts of robots and types of robots.
2. To educate on various path planning techniques.
3. To discuss about the various applications of robots.
4. To familiarize about material handling in a system.

Course Content

Introduction: Definition, automation principles and strategies - scope of automation - socioeconomic consideration, low cost automation - Production concepts and automation strategies - Fixed Automation: Automated Flow lines, Methods of Work part Transport. Transfer Mechanism - Continuous transfer, intermittent transfer - Indexing mechanism Automation for Machining Operations, Design and Fabrication Considerations. Analysis of Automated Flow Lines: General Terminology and Analysis.

Fundamentals of robotics – wrists design - end effectors – actuators - modular robots. Trajectory planning: Mathematical representation of Robots - Position and orientation Homogeneous Transformation - Various joints- Representation using the Denavit Hattenberg parameters - Degrees of freedom - Direct Kinematics-Inverse kinematics - Linear and angular velocities - Manipulator Jacobian - Prismatic and rotary joints Inverse -Wrist and arm singularity - Static force analysis.

Material handling: concepts of material handling, principles and considerations in material handlingsystems design, conventional material handling systems- industrial trucks, rail guided vehicles, conveyor systems, advanced material handling systems, automated guided vehicle systems, automated storage and retrieval systems (ASRS), Work-in-process Storage, Interfacing Handling and Storage with Manufacturing

Automated Inspection and Testing: Automated Inspection Principles and Methods, Sensor Technologies for Automated Inspection, Coordinate Measuring Machines, Other Contact InspectionMethods, Machine Vision, Other optical Inspection Methods. Robotic vision systems, image representation, object recognition and categorization, depth measurement, image data compression,visual inspection

Other applications: Application of Robots in welding, Spray painting, assembly operation, cleaning,robot for underwater applications. Robot cell design – control – recent developments and special applications - Micro and Bio robotics. Factors influencing the choice of a robot, robot performance testing - Impact of robot on industry and society.

Text Books

1. *Ashitava Ghoshal, Robotics Press, Sixth impression, 2010. Hill Education Pvt. Ltd, 2010.*
2. *Richard D Klafter, Thomas Achmielewski and Michael Negin," Robotics Engineering: AnIntegrated Approach" Parentice Hall India, New Delhi,2001*
3. *Deb S R and Deb S, "Robotic Technology and Flexible Automation", Tata McGraw Hill,2010*
4. *Mikell P Groover, "Automation, Production Systems, and Computer-Integrated Manufacturing", Pearson Education, 2015.*

Reference Books

1. *Stephen J. Derby, "Design of Automatic Machinery", Special Indian Edition, MarcelDecker, New York, Yesdee publishing Pvt. Ltd, Chennai, 2004.*
2. *J J Craig, ―Introduction to Robotics: Mechanics and Control, Prentice Hall, 2004.*
3. *R M Murray, Z. Li and S S Sastry, "A Mathematical Introduction to Robotic Manipulation", CRC Press, 1994.*

Course Outcomes

On completion of this course, the students will be able to

1. Explain the basic concepts of working of robot.
2. Apply their knowledge in handling the materials.
3. Analyze instrumentation systems for inspection and testing.
4. Use robots in different applications.

Course Code	**:**	**IC 608**
Course Title	**:**	**AI and Robotics Laboratory**
Number of Credits	**:**	**2**
Course Type	**:**	**Laboratory**

Course Learning Objectives

1. Impart knowledge on Robot programming and Robot operation control.
2. Expose students to SCADA and various data communication protocols.
3. To learn the ML and DL models.
4. To implement the DL models for real time data.

List of Experiments

1. Operator control of Robot and jog the Robot.
2. Robot Programming: “In-air” program (Point to Point motion).
3. Robot programming: Fillet joint weld, circular joint weld and Linear joint weld.
4. Actuation of Pneumatic circuit for Rotary Pusher Module and interface with ProgrammableLogic Control.
5. Actuation of Single Acting Cylinder using a two-way Pressure Valve using Flow ControlValve.
6. Trouble Shooting the Sensor and Actuator using MAPS-6S Multistation.
7. Simulation of movements in HMI and SCADA (using Analog data).
8. Signal processing (A/D and D/A) using SCALEX and NORMX Blocks.
9. Execute an Instruction from the cloud to stop the machine operation.
10. Integration of MAPS-6S Automation Kit using Profinet Protocol.
11. Configure and Visualize the Thing data using OPC-UA Protocol.
12. Configure and Visualize the Thing data using Modbus adapter.
13. Algorithm for Data pre-processing.
14. Development of regression algorithms for the given data.
15. Implementation of classification algorithms.
16. Development of Deep network models.
17. Application and case studies related to manufacturing industries.
18. Application and case studies related to process industries.

Course Outcomes

Upon completion of the course, students will be able to

1. Understand the operation of robot, select a robot program and execute, stop and reset it inthe required operating modes.
2. Understand the process of conversion of digital data to analog and analog data to digitaldata for automation and gain adequate programming skills using PLC, DCS and SCADA.
3. Understand the AI concepts.
4. Implement the ML and DL concepts.

Course Code	**:**	**IC 611**
Course Title	**:**	**Artificial Intelligence in Industrial Automation**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objective

1. To identify potential areas for automation and justify need for automation
2. Study the concepts of Artificial Intelligence.
3. Learn the methods of solving problems using Artificial Intelligence.
4. Apply the concepts of AI to attain industrial automation

Course Content

Introduction to Artificial Intelligence – Introduction - Foundations of AI- History of AI Intelligent agents: Agents and Environment- Reactive agent- deliberative- goal-driven, utility driven, and learning agents.

Machine learning: Supervised learning– Classification methods-Nearest neighbor- Decision trees-Linear discriminant Analysis - Logistic regression- Support Vector Machines Unsupervised learning: Clustering- Clustering Methods-Partitioned based Clustering - K-means- K-medoids; Hierarchical Clustering - Agglomerative- Divisive- Distance measures.

Structure and function of a single neuron; Artificial Neural Networks (ANN); Single-layer networks; Perceptron-Linear separability, Training algorithm, Limitations; Multi-layer networks-Architecture, Back Propagation Algorithm (BTA) training algorithms; Recurrent Networks; Feed-forward networks; Radial-Basis-Function (RBF) networks.

Typical applications of ANNs: Classification, Function Approximation, Forecasting, Control, Optimization.-Reinforcement learning, Basics of Deep Learning-CNN-LSTM.

Applications of Artificial Intelligence- ML and DL models in Manufacturing-Health Monitoring-Predictive Maintenance.

Text Books

1. Rich and Knight, “Artificial Intelligence”, 3rd Edition, Tata McGraw Hill, 2014.
2. Ethem Alpaydin, “Machine Learning the New AI”, MIT press, 2016.
3. Ian Good Fellow, Yoshua Bengio, Aaron Courville, DEEP LEARNING - The MIT Press (18 November 2016).

Reference Books

1. Stuart Russell and Peter Norvig, "Artificial Intelligence - A Modern Approach", 4th Edition, Pearson, 2020.
2. Richard E. Neapolitan, and Xia Jiang, "Artificial Intelligence -With an Introduction to Machine Learning", 2nd Edition, CRC press, 2018.
3. *Anuradha Srinivasaraghavan, Vincy Joseph "Machine Learning", Wiley, 2019*
4. *Wolfgang Ertel," Introduction to Artificial Intelligence", Second Edition, Springer, 2017.*
5. *Rajiv Chopra, "Deep Learning", 1st edition, Khanna Publishing House, 2018.*
6. *Deepak Khemani, "A First Course in Artificial Intelligence", McGraw Hill Education, 2013.*

Course Outcomes

On completion of this course, the students will be able to

1. Understand basic AI algorithms.
2. Identify appropriate AI methods to solve a given problem.
3. Acquire knowledge about AI/ ML/DL techniques in Industrial automation.
4. Understand the levels of automation.

Course Code	**:**	**IC 613**
Course Title	**:**	**Modelling Simulation and Analysis of Manufacturing Systems**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. Understand a model and document a problem.
2. Study different techniques to generate random variate.
3. Use the different simulation language to model and analyze problems found in industrial automation.
4. To design and analyze a simulation experiment.

Course Content

Principles of Modeling & Simulation -Basic Simulation Modeling, appropriate simulation, not appropriate simulation, Advantages and disadvantages and pit falls of simulation, Monte - Carlo Simulation, Areas of applications, Discrete and Continuous Systems, Modeling of a system, Types of models, Discrete event simulation.

Modeling Approaches - Modeling complex systems, List processing in simulation, Simple simulation language, Single server queuing systems, Time shared computer model, Multiteller banking with jockeying, Job shop model.

Random Number Generation -Basic probability and statistics- random variables and their properties, Properties of random numbers, generation of pseudo random numbers, Techniques for generating random numbers, Various tests for random numbers-frequency test, and test for autocorrelation.

Random Variate Generation -Introduction, Different techniques to generate random variate: Inverse transform technique, Normal, Uniform, Weibull, Direct transformation technique for normal and log normal distribution, Convolution method and acceptance rejection techniques-Poisson distribution, Output Data Analysis for a single system -Types of simulation with respect to output analysis, transient and steady state behavior of a stochastic process.

Statistical Techniques - Comparison of two system design, Comparison of several system design – Bonferroni approaches to multiple comparisons for selecting best fit, for screening, Variance reduction techniques such as simple linear regression, multiple linear regression.

Simulation Studies -Simulation of inventory problems, Discrete event simulation problems, Experimental design and optimization, 2k factorial designs, Simulation of manufacturing systems.

Text Books

1. *Jerry Banks, John Carson, Barry L. Nelson, David Nicol, "Discrete - Event Systems Simulation", 4th edition, Prentice Hall, 2011.*
2. *Averill Law & David M. Kelton, "Simulation, Modelling and Analysis", TMH, 4th Edition, 2007.*

Reference Books

1. *Guy L. Curry, Richard M. Feldman, "Manufacturing Systems Modeling and Analysis", Second Edition, Springer-Verlag Berlin Heidelberg, 2011.*
2. *Richard A. Johnson, "Probability and Statistics for Engineers", 8th edition,Pearson, 2010.*
3. *Geoffrey Gordon, "System Simulation", Prentice Hall, 2nd edition, 2009.*

Course Outcomes

On completion of this course, the students will be able to

1. Analyze, model, and select appropriate input distributions and to explain simulation time advance mechanisms.
2. Understand types of simulation with respect to output analysis.
3. Apply appropriate simulation statistical output techniques.
4. Develop and apply appropriate random number and random variable generation techniques.

Course Code	**:**	**IC 615**
Course Title	**:**	**Embedded Systems**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To provide knowledge on building blocks of embedded system, input/output interfacing & Bus communication with processors.
2. To teach automation using scheduling algorithms and real time operating system.
3. To discuss on different phases & modeling of a new embedded product.
4. To involve discussions/ practice/exercise onto revising & familiarizing the concepts

Course Content

Introduction to Embedded Systems –built in features for embedded Target Architecture – selection of Embedded processor –DMA-memory devices –Memory management methods-memory mapping, cache replacement policies-Timer and Counting devices, Watchdog Timer, Graphics Processing Unit (GPU) - multiprocessing and parallel processing**,** Real Time Clock - Software Development tools-IDE, assembler, compiler, linker, simulator, debugger, In circuit emulator, Target Hardware Debugging.

Embedded Networking: Introduction, I/O Device Ports & Buses - multiple interrupts and interrupt service mechanism – Serial Bus communication protocols - RS232 standard–RS485–USB–Inter Integrated Circuits (I2C) - CAN Bus – Wireless protocol based on Wifi, Bluetooth, Zigbee – Introduction to Device Drivers - interfacing peripherals with processors - Configuration of networking modules - timing and control signals.

Introduction to basic concepts of RTOS-Need, Task, process & threads, interrupt routines in RTOS, Multiprocessing and Multitasking, Preemptive and non-preemptive scheduling, Task communication-context switching, interrupt latency and deadline shared memory, message passing-, Interprocess Communication –synchronization between processes-semaphores, Mailbox, pipes, priority inversion, priority inheritance, comparison of Real time Operating systems: VxWorks, µC/OS-II, RT Linux, Edge computing - Introduction, Edge Operating system Virtual machine, selection of operating system for edge computing, Comparison of Windows and Linux based Edge operating systems, Edge devices, Edge devices in IoT applications.

Modelling embedded systems-embedded software development approach --Overview of UML modeling with UML, UML Diagrams--Hardware/Software Partitioning, Co-Design Approaches for System Specification and modeling - CoSynthesis-features comparing Single-processor Architectures & Multi-Processor Architectures--design approach on parallelism in uniprocessors & Multiprocessors.

Application development: Objective, Need, different Phases &Modelling of the EDLC. choice of Target Architectures for Embedded Application Development-for Control Dominated-Data Dominated Systems-Case studies on Digital Camera, Adaptive Cruise control in a Car, Mobile Phone, automated robonoids, interface to sensors, GPS, GSM, Actuators.

Text Books

1. *Tammy Noergaard, "Embedded System Architecture, A comprehensive Guide for Engineers and Programmers", 2nd Edition, Elsevier, 2013.*
2. *Peckol, "Embedded system Design", JohnWiley&Sons,2010.*
3. *Lyla B Das," Embedded Systems-An Integrated Approach", Pearson 2013.*

Reference Books

1. *Elicia White, "Making Embedded Systems", O'Reilly Series, SPD, 2011.*
2. *Wolf Wayne Hendrix, Computers as Components: Principles of Embedded Computing System Design, 3rd Edition, Morgan Kaufmann, 2012.*
3. *Shibu K.V, "Introduction to Embedded Systems", TataMcgraw Hill,2009.*
4. *Raj Kamal, "Embedded System-Architecture, Programming, Design", Mc Graw Hill, 2013.*

Course Outcomes

On completion of this course, the students will be able to

1. Understand the functionalities of processor internal blocks, with their requirement.
2. Understand the role and features of RT operating system, that makes multitask execution possible by processors.
3. Understand multiple CPU based on either hardcore or soft core helps data overhead management with processing- speed reduction for µC execution.
4. To design embedded systems to perform dedicated function.

Course Code	**:**	**IC 617**
Course Title	**:**	**Intelligent Transportation Systems**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. This course covers the techniques used to improve the safety, efficiency and control of surface transportation systems.
2. Emphasis is placed on technological and operational issues of these systems and using them for incident detection and for intelligent traffic management.
3. This course provides the current and future Intelligent Transportation Systems (ITS) workforce with flexible, accessible ITS learning through training and educational resources.
4. This course will assist graduate students, educators and transportation professionals in developing their knowledge, skills and abilities to build technical proficiency for ITS.

Course Content

The Road to ITS – History of traffic congestion, Traditional approach to addressing demand vs. capacity, Development of a modern ITS approach, Costs and benefits, Making the case for ITS.

Systems Engineering and ITS Architecture – Defining systems engineering and its application to ITS, Benefits of developing ITS architecture, ITS service categories, Regional ITS architecture, Integrating ITS planning with the transportation planning process.

Elements of ITS Design – Interdisciplinary engineering coordination with ITS, Powering ITS equipment, Detection technologies and data collection and distribution, Field device site design considerations, Communications infrastructure.

The Backbone of ITS – Communications network topologies and configuration, Bandwidth requirements, Attributes of hardwired and wireless networks, Fiber-optic networks, Computer IT and ITS synergies. Connected Vehicles – Vehicle-to-vehicle and vehicle-to-infrastructure communications, Safety applications and connected vehicle safety pilot program, Communications security and legal liability, Interoperability and international initiatives.

System Operations and Maintenance – The ITS business, Constructability, Plans, specifications, and cost estimate deliverable package, Maintenance considerations during design, Operational challenges, Ongoing system maintenance, Budgeting support after initial deployment.

Text Books

1. *Robert Gordon, "Intelligent Transportation Systems: Functional Design for Effective Traffic Management", Second Edition, Springer NY, 2016.*
2. *Ghosh, S., Lee, T.S, "Intelligent Transportation Systems: New Principles and Architectures", CRC Press, 2000.*

Reference Books

1. *Joseph M. Sussman, "Perspectives on Intelligent Transportation Systems (ITS)", Springer, NY, 2010.*
2. *Mashrur A. Chowdhury, Adel Sadek, "Fundamentals of Intelligent Transportation Systems Planning", Artech House, 2003.*

Course Outcomes

Upon completing this course, the student will be able to

1. Study the modern transport systems in a systematic and focused way.
2. Understand the fundamentals of ITS, including ITS national/regional architectures, designing process and the state-of-the-practice technologies.
3. Grasp technological and operational issues of ITS and using them for connected vehicles.
4. Think mobility further through adaptable and modular solutions.

Course Code	**:**	**IC 619**
Course Title	**:**	**Fluid Power Systems**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To understand the role of pneumatic and hydraulic systems in industrial automation.
2. To impart the principles of various pneumatic and hydraulic components.
3. To facilitate the design of hydraulic and pneumatic circuits.
4. To familiarize the operation, maintenance and troubleshooting of various fluid power system in industry.

Course Content

Introduction to fluid power, applications, advantages and limitations. Types of fluid power systems, Properties, Types of fluids – Fluid power symbols. Basics of hydraulics - applications of Pascal's Law – Laminar and Turbulent flow – Reynolds's number – Darcy's equation – Losses in pipe, valves and fittings.

Hydraulic system and components: Hydraulic Pumps – Classification, reciprocating, rotary, centrifugal, working principle, performance characteristics, selection and design considerations. Fluid Power Actuators – Linear hydraulic actuators and types – Semi-rotary and rotary actuators.

Pneumatic system and components: Introduction to Pneumatics – Compressors – Types – Air treatment – FRL Unit – Air control valves, Quick exhaust valves, pneumatic actuators. Fluid power circuit design, Speed control circuits, synchronizing circuit, Pneumo-hydraulic circuit, Sequential circuit design.

Design of fluid power circuits: Control Valves – Directional, Pressure and Flow control valves. Accumulators – Types, Accumulators circuits. Intensifier – Applications – Intensifier circuit. Servo systems – Hydro mechanical servo systems, Electro hydraulic servo systems and proportional valves.

Fluid power system maintenance and troubleshooting: Fluidics – Introduction to fluidic devices. Fluid power circuits; failure and troubleshooting.

Text Books

1. *Vickers. Industrial Hydraulics Manual, 6th ed., Eaton Hydraulics Training Services, 2015.*
2. *Anthony Esposito, Fluid Power with Applications, 7th ed., Pearson Education India,2013.*
3. *Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, 2nd ed., Pearson, 1986.*
4. *P. Joji, Pneumatic Controls, 1st ed., Wiley India, 2008.*

Reference Books

1. *Srinivasan. R, Hydraulic and Pneumatic controls, 2nd ed., McGraw Hill Education, 2008.*
2. *Majumdar. S, Pneumatic systems – Principles and maintenance, 1st ed., Tata McGraw Hill Education, 2017.*
3. *Michael J, Pinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1988.*

Course Outcomes

On completion of this course, the students will be

1. Understand the basics of fluid power system.
2. Select the appropriate pneumatic and hydraulic system for a given application.
3. Implement various fluid power circuits.
4. Operate, maintain and troubleshoot industrial fluid power circuits.

Course Code	**:**	**IC 621**
Course Title	**:**	**Advanced Control System**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To impart knowledge in characteristics and performance of feedback control system.
2. To introduce about the system states and state-space modeling of dynamical systems.
3. To teach the advanced methods and techniques of linear system analysis and stability using Lyapunov theory.
4. To develop practical control systems using digital computers through data acquisition and computing.

Course Content

Introduction to basic control theory, Requirements for Control System Design, Mathematical Models for Control, Control System‘s Characteristics, Performance Specifications for Linear Systems.

State-space Models – Review of vectors and matrices, Canonical Models from Differential Equations and Transfer Functions, Interconnection of subsystems. Analysis of Linear State Equations – First order scalar differential equations, System modes and model decomposition, State Transition Matrix, Time-varying matrix case.

Lyapunov’s stability theory for Linear Systems – Equilibrium points and stability concepts, Stability definitions, linear system stability, The Direct method of Lyapunov, Use of Lyapunov’s method in feedback design.

Controllability & Observability – Definitions, Controllability/Observability Criteria, Design of state feedback control systems, Full-order and Reduced-order Observer Design, Kalman canonical forms, Stabilizability & Detectability.

Digital Control Systems, Closed-loop Feedback Sampled-Data Systems, Stability Analysis, Implementation of Digital Controllers.

Text Books:

1. *Katsuhiko Ogata, Modern Control Engineering, PHI Learning Private Ltd, 5th Edition, 2010.*
2. *Franklin, G.F., David Powell, J., Emami-Naeini, A., Feedback Control of Dynamic Systems, Prentice Hall, 7th Edition, 2014.*
3. *Dorf, R.C., Bishop, R.H., Modern Control Systems, Prentice Hall, 13th Edition, 2016.*
4. *Brogan, W.L., Modern Control Theory, Prentice Hall, 3rd Edition, 1990.*

Reference Books:

1. *John J.D., Azzo Constantine, H. and Houpis Stuart, N Sheldon, Linear Control System Analysis and Design with MATLAB, CRC Taylor& Francis Reprint 2009.*
2. *I.J. Nagrath and M. Gopal, Control Systems Engineering, New Age International Publishers, 6th Edition, 2017.*
3. *William A. Wolovich, Automatic Control Systems, Oxford University Press, 1st Indian Edition 2010.*

Course Outcomes

On completion of this course, the students will be,

1. Exposed to an appropriate modern paradigm for the study of larger scale multi-input-multi- output systems.
2. Able to use linear algebra and matrix theory in the analysis and design of practical control systems.
3. Able to determine the stability of systems using Lyapunov's theory.
4. Motivated to implement modern control systems using a digital computer.

Course Code	**:**	**IC 623**
Course Title	**:**	**System Identification**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To impart knowledge about the importance of system identification.
2. To introduce empirical and data based modeling of large-scale systems.
3. To train the students in parametric and nonparametric statistical models and estimation techniques.
4. To expose the students to the algorithms and computational overheads involved in large-scale system modeling and control.

Course Content

Review of linear systems, stochastic process- statistical properties, signal stationarity, auto-correlation, cross-correlation, and power spectra - System identification Procedure- Experimental design – Input design for identification, notion for persistent excitation (pulse, step, pseudo random binary sequence (PRBS), and white noise) - data processing - Model structure determination - Estimation techniques - Model validation.

Nonparametric model estimation: Correlation and spectral analysis for non-parametric model Identification, obtaining estimates of the plant impulse, step and frequency responses from Process data.

Parametric model structures: Time series models (AR, MA, ARMA, ARIMA, ARX, ARMAX, OE, BJ models) – Order determination of time series models using correlation- prediction error models of parametric models.

Linear regression - Least square estimates, statistical properties of LS Estimates- bias & consistency, Weighted least squares, maximum likelihood estimation, Instrumental variable method- square Residual analysis for determining adequacy of the estimated models.
Recursive Algorithms: Least squares, Instrumental Variables, extended least square, prediction error methods. Kalman filter, Extended Kalman filtering and its applications.

Simulation study for different processes: Design of experiment, nonparametric identification, parametric identification, influence of different inputs on ARX, ARMAX modelling, use of identified model for fault diagnosis, estimation, prediction and control of the process.

Text Books

1. *Arun K. Tangirala, "Principles of System Identification: Theory and Practice", 1st Edition, CRC Press, 2014.*
2. *L. Ljung, "System Identification: Theory for the User", 2nd Edition, Prentice- Hall, 1999.*
3. *Rolf Johansson, "System Modeling and Identification", Prentice Hall, 1993.*

Reference Books

1. *Karel J. Keesman, "System Identification an Introduction", Springer-Verlag London, 2011.*
2. *Y. Zhu, "Multivariable System Identification for Process Control",1st Edition, Pergamon Elsevier Science, 2001.*
3. *O. Nelles, "Nonlinear System Identification", Springer-Verlag Berlin Heidelberg, 2001.*
4. *B. Roffel and B. Betlem, "Process Dynamics and Control", Wiley, 2006.*

Course Outcomes

On completion of this course, the students will be able to

1. Conduct experiments, design suitable inputs and generate data for system identification.
2. Identify the model structure & order determination for an unknown process from empirical data.
3. Apply estimation techniques for parametric & nonparametric models.
4. Identify and validate the model for practical process applications.

Course Code	**:**	**IC 625**
Course Title	**:**	**Building and Infrastructure Systems and Automation**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. Understand, illustrate the need and concept of building, infrastructure subsystems, systems & automation.
2. Select, architect, size, design and implement the building & infrastructure main & auxiliary sub-systems, systems, automation.
3. Perform and improve operations & maintenance of building, infrastructure subsystems, systems automation including energy & utility optimization.
4. Learn recent trends, research-topics, expansion areas of Building & Infrastructure system automation & management.

Course Content

Introduction to Building & Infrastructure Systems & Automation:
Overview of buildings & campuses – residential community, commercial, industrial, Concept and application of buildings automation (BA), Requirements and design considerations of BA. Effect on energy & utility services efficiency of building services operations. Architecture and components of BA, BMS (Building Management Systems) concept and overview.

Beyond traditional buildings: Other important infrastructures – commercial/industrial campuses, malls, high-rise buildings, hotels & resorts, sports-complex, smart-community & smart-city, metro-trains, airports, seaports, ships, surface transports (road-bridges, highways, waterways).

Buildings & Infrastructure Systems: Typical subsystems HVAC**:** Different components of HVAC system like heating, cooling system, chillers, AHUs, compressors, distribution systems, air-quality, filters units and their types, operational efficiency and economics, Community/district heating & cooling.

Lighting and Access control systems: Various components of lighting systems, efficient use of electricity, lighting control systems, components of CCTV system like cameras, cables, etc., concept of automation in access control system.

Vertical transportation System: Structure of lift and escalator, traffic analysis, lift drives, supervisory control and remote monitoring of lift, safety aspects.

Fire & Alarm system: Different fire sensors, smoke detectors and their types, CO and CO_2 sensors, Fire control panels, design considerations for the FA system concept of IP enabled fire & alarm system, design aspects and components of PA system.
Other utility & subsystems: Water sources-storage-distribution, rain-water harvesting, sewage treatment plants, swimming pool, cooking gas source-distribution system, community halls & gym, air/gas utility supply & distribution systems, facility-estate management, safety, O&M.

Electrical Utility: Typical sources - power-grid utility & diesel-gensets, stable and uninterrupted power supply, components of electrical power distribution in buildings- infrastructure, transformers, meters, distribution system components, wiring, common/large loads – pumps, compressors, motors & drives, VFDs.

Building Automation: Role of automation in operation of B&I System/subsystems (HVAC/Lighting/Lifts/Electricity etc.). Relevant sensors-actuators, BA controllers DDC, PLC, SCADA, HMI, RMVCD Centers.

Energy management systems: Bureau of Energy Efficiency (BEE) standards, concept of energy management systems, Energy Optimization, Green-energy & Zero-energy Buildings, Certification.

Thermal energy: Sources-distribution-sinks components, thermal energy systems modeling & simulation for buildings/infrastructure, Heat-recovery, Solar heating, typical simulation tools Electrical energy & microgrids: Sources-distribution-sinks components, power-utility grid, diesel-gas gensets, Campus Micro-grids -- renewable energy sources (solar/wind/battery storage etc.), CHP, electrical vehicle charging infrastructure, electrical energy systems modeling & simulation for buildings/infrastructure, typical simulation tools.

Self-Study Topics:
Recent & Advanced Topics:
Overview of recent trends/topics like Automation for special buildings/infrastructures like metros, airports, seaports, high-rise buildings, hotels & resorts, sports-complex, smart-community, smart-city etc.; Microgrid advances, BMS, Cybersecurity, Optimization, AI-ML in BMS, assets & human-comforts analytics, post-pandemic health & safety trends in BMS, etc.

Reference Books

1. *Smart Buildings by Jim Sinopoli, Butterworth-Heinemann imprint of Elsevier, 2nd ed., 2010.*
2. *Understanding Building Automation Systems (Direct Digital Control, Energy Management, Life Safety, Security, Access Control, Lighting, Building Management Programs) by Reinhold A. Carlson, Robert A. Di Giandomenico, pub. by R.S. Means Company, 1991.*
3. *Intelligent Building Systems by Albert Ting-Pat So, WaiLok Chan, Kluwer Academic publisher, 3rd ed., 2012.*
4. *Design of Special Hazards and Fire Alarm Systems by Robert Gagnon, Thomson DelmarLearning; 2nd edition, 2007.*
5. *HVAC Controls and Systems by Levenhagen, John I.Spethmann, Donald H., McGraw-Hill Pub.*
6. *HVAC Control in the New Millennium by Hordeski, Michael F, Fairmont press, 2001.*
7. *Process Control- Instrument Engineers Handbook by Bela G. Liptak, Chilton book co.*
8. *Other resources like Published journal/conference papers, industrial products & manuals, Internet search/survey.*

Course Outcomes

On completion of this course, the students will be able to

1. Understand the architecture and basic building blocks of Building and Infrastructure of Automation systems
2. Design and evaluate various subsystems for Building Automation systems
3. To design and implement control strategies for HVAC systems for energy management system
4. Grasp the advanced principles for incorporating the safety and acquire efficient resource management skills within Building Automation systems.

Course Code	**:**	**IC 612**
Course Title	**:**	**Industrial Internet of Things**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To provide a good understanding of Internet of Things (IoT) and its envisioned deployment domains.
2. To provide an understanding of smart sensors/actuators with their internet connectivity for experimentation and designing systems.
3. To provide a overview about the various protocol standards deployed in the Internet of Things (IoT) domain and to make informed choices.
4. To impart knowledge in the design and development of IoT systems with enablement ensuring security and assimilated privacy.

Course Content

Introduction to Internet of Things - Overview of Internet of Things- the Edge, Cloud and the Application Development, Anatomy of the Thing, Industrial Internet of Things (IIoT - Industry 4.0), Quality Assurance, Predictive Maintenance, Real Time Diagnostics, Design and Development for IoT, Understanding System Design for IoT, Design Model for IoT.

System Design of Connected Devices - Embedded Devices, Embedded Hardware, Connected Sensors and Actuators, Controllers, Battery Life Conservation and designing with Energy Efficient Devices, SoCs, CC3200, Architecture, CC3200 Launchpad for Rapid Internet Connectivity with Cloud Service Providers.

Understanding Internet Protocols - Simplified OSI Model, Network Topologies, Standards, Types of Internet Networking – Ethernet, WiFi, Local Networking, Bluetooth, Bluetooth Low Energy (BLE), Zigbee,6LoWPAN, Sub 1 GHz, RFID, NFC, Proprietary Protocols, SimpliciTI, Networking Design – Push,Pull and Polling, Network APIs.

System Design Perspective for IoT – Products vs Services, Value Propositions for IoT, Services in IoT, Design views of Good Products, Understanding Context, IoT Specific Challenges and Opportunities.

Advances Design Concepts for IoT – Software UX Design Considerations, Machine Learning and Predictive Analysis, Interactions, Interusability and Interoperability considerations, Understanding Security in IoT Design, Design requirements of IoT Security Issues and challenges, Privacy, Overview of Social Engineering.

Text Books

1. *Joe Biron& Jonathan Follett, Foundational Elements of an IoT Solution – The Edge, The Cloud and Application Development, Oreilly,1st Edition, 2016.*
2. *Elizabeth Goodman, Alfred Lui, Martin Charlier, Ann Light, Claire Rowland, "Designing Connected Products UX for the Consumer Internet of Things", 2nd Edition,2013.*
3. *The Internet of Things (A Look at Real World Use Cases and Concerns), Kindle Edition, Lucas Darnell, 2016.*

Reference Books

1. *Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress 1st ed. Edition, 2017.*
2. *Olivier Hersent, "The Internet of Things: Key Applications and Protocols", Wiley 2nd Edition, 2012.*
3. *The Internet of Things – Opportunities and Challenges*
4. *http://www.ti.com/ww/en/internet_of_things/pdf/14-09-17-IoTforCap.pdf*
5. *Single Chip Controller and WiFi SOC*
6. *http://www.ti.com/lit/ds/symlink/cc3200.pdf*
7. *Wireless Connectivity Solutions*
8. *http://www.ti.com/lit/ml/swrb035/swrb035.pdf*
9. *Wireless Connectivity for the Internet of Things – One size does not fit all*
10. *http://www.ti.com/lit/wp/swry010/swry010.pdf*

Course Outcomes

On the completion of this course, the students will be able to

1. Understand the design architecture of IoT.
2. Make choice of protocols and deployment in solutions.
3. Comprehend the design perspective of IoT based products / services.
4. Basic understanding of various Industrial IoT platforms

Course Code	**:**	**IC 614**
Course Title	**:**	**Computer Vision and Image Processing**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To introduce the students to the emerging fields.
2. To familiarize with both established and emergent methods, algorithms and architectures.
3. To enable the students to apply computer vision and image processing techniques to solve various real-world problems, and develop skills for research in the field.
4. To impart practical skills necessary to build computer vision applications.

Course Content

Image Formation and Coordinate Transformations, Camera Matrix, Motion/Stereo Pin-hole model, Human eye, cognitive aspects of colour, 3D space; illumination; Sampling and Quantization, Coordinate transformations and camera parameters.

Image Processing - Noise Removal, Blurring, Edge Detection: Canny – Gaussian, Gabor, Texture Edges, Curvature, Corner Detection. Motion Estimation: Horn-Schunk Optical Flow Formulation, Euler-Lagrange formulation: Calculus of variations theory. Structure Recovery from Motion.

Segmentation - Concept of Figure vs. Ground, Watershed, Change Detection, Background Subtraction, Texture Segmentation, Gaussian Mixture Models - Applications in Color and Motion based Image Segmentation, Background Modeling and Shape Clustering.

Machine Learning techniques in Vision, Bayesian Classification, Maximum Likelihood Methods, Neural Networks; Non-parametric models; Manifold estimation, Support Vector Machines; Temporal sequence learning.

Introduction to Object Tracking - Exhaustive vs. Stochastic Search Shapes, Contours, and Appearance Models. Mean-shift tracking; Contour-based models.

Object Modeling and Recognition Fundamental matrix and Epipolar geometry, Adaboost approaches: Face Detection and Recognition, Large Datasets; Attention models.

Applications: Surveillance, Object detection etc.

Hall 2011.

Text Books

1. *D. Forsyth and J. Ponce, Computer Vision: A Modern Approach, 2nd Edition, Prentice.*
2. *Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2011.*

Reference Books

1. *E.R. Davies, Machine Vision, Theory Algorithms Practicalities, Elsevier, 2005.*
2. *Richard O. Duda, Peter E. Hart, and David G. Stork, Pattern Classification, 2nd ed., Wiley Asia, 2002.*
3. *Richard Szeliski, Computer Vision: Algorithms and Applications, Springer; 2011.*
4. *Simon J.D. Prince, "Computer Vision: Models, Learning, and Interference", Cambridge University Press, 2012.*
5. *R. Gonzalez and R. Woods, Digital Image Processing, 3rd Ed, Prentice Hall 2007.*

Course Outcomes

On completion of this course, the students will be able to

1. Understand the major concepts and techniques in computer vision and image processing
2. Demonstrate computer vision and image processing knowledge by designing and implementing algorithms to solve practical problems
3. Understand the type of algorithm required for a particular image processing task
4. Implement common methods for robust image matching and alignment

Hall 2011.

Course Code	**:**	**IC 616**
Course Title	**:**	**Predictive Analytics**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. Ability to develop and use various predictive models based on various regressionand decision tree methods.
2. Understand how to formulate predictive analytics questions.
3. Learn how to select the appropriate method for predictive analysis.
4. Learn how to search, identify, gather and pre-process data for the analysis.

Course Content

Statistical Learning and Linear Regression- Supervised versus unsupervised learning, the trade-Off between prediction accuracy and model interpretability, Regression versus classification problems, Simple linear regression, Multiple linear regression, Considerations inthe regression model, Comparison of linear regression with K-Nearest Neighbors, Weighted Least Squares (WLS), Generalized Linear Models (GLM).

Overview of Classification and data processing- Logistic Regression - Logistic model, Estimating the regression coefficients, Making predictions, Multiple logistic regression, Linear Discriminant Analysis- Using Bayes' theorem for classification, Quadratic Discriminant Analysis, Comparison of classification methods, Data preprocessing- Overview, Variable types, Data transformations, Count data models, Centering, Standardization, Rank transformations, Data reduction.

Linear Model Selection and Regularization- Subset selection, Dimension reduction methods-Principal components regression, Partial least squares, Considerations in high dimensions, regression in high dimensions. Tree-Based Methods- The basics of decision trees, Regression trees, Classification trees, Trees versus linear models, Advantages and disadvantages of trees, Bagging, Random forests, Boosting.

Predictive Modelling - Statistical concepts – Basics, Introduction to predictive modelling, Neural networks and other modelling tools, Model assessment and implementation, Support Vector Machine (SVM), Cross tabulation and correlation analysis.

Unsupervised Learning- The challenge of unsupervised learning, Principal Components Analysis (PCA), Use of principal components, Clustering methods, K-means clustering, Hierarchical clustering

Machine Learning - Machine learning overview, Error measures, Cross-validation, Bias vs. variance tradeoff.

Text Books

1. *Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey,"Business analytics Principles, Concepts, and Applications", by Pearson FT Press,2014.*
2. *James Evans," Business Analytics", 1st Edition, Persons Education,2012.*

Reference Books

1. *Gareth James, Daniela Witten, Trevor Hastie Robert Tibshirani, "An Introduction toStatistical Learning with Applications in R",1st Edition, Springer, 2017.*
2. *Lander, J., "R for Everyone: Advanced Analytics and Graphics", 1 edition Addison-Wesley Data & Analytics Series, 2013.*

Course Outcomes

On completion of this course, the students will be able to

1. Develop a deep understanding of the predictive analytics life cycle.
2. Work with various data types and how to pre-process the data for analysis.
3. Learn the basic concepts behind machine learning.
4. Learn the various methods to build predictive classification models using decision trees.

Course Code	**:**	**IC 618**
Course Title	**:**	**Wireless Sensor Networks**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To overview the various design issues and challenges in the layered architecture of Wireless sensor networks.
2. Analyze various protocols used in wireless sensor networks.
3. To familiarize localization and tracking in networks
4. Learn about data handling in wireless sensor networks.

Course Content

Introduction to Sensor Networks - Unique constraints and challenges, Advantage and Applications of Sensor Networks, Enabling technologies for Wireless Sensor Networks. Sensor Node Hardware and Network Architecture: Single-node architecture, Hardware components & design constraints, Operating systems and execution environments, Network architecture, Optimization goals and figures of merit, Design principles for WSNs, Service interfaces of WSNs, Gateway concepts.

Physical layer- Introduction, wireless channel and communication fundamentals – frequency allocation, modulation and demodulation, wave propagation effects and noise, channels models, spread spectrum communication, packet transmission and synchronization, quality of wireless channels and measures for improvement, physical layer and transceiver design consideration in wireless sensor networks.

Data link layer- Fundamentals of wireless MAC protocols, Characteristics of MAC protocol in wireless sensor networks contention-based protocols, Contention free MAC protocols, Hybrid MAC protocols Network layer-routing metrics -Flooding and gossiping. Routing protocols: Issues in designing routing protocols, Classification of routing protocols, Energy-efficient routing, Unicast, Broadcast and multicast, Geographic routing.

Localization and tracking – A tracking scenario, tracking multiple objects, sensor models, performance comparison and metrics, Networking sensors – MAC, general issues, geographic energy – aware routing, Attribute – Based routing. Deployment and Configuration: Localization and positioning, Coverage and connectivity, Single-hop and multi-hop localization, self-configuring localization systems, sensor management

Data Storage and Manipulation: Data centric and content-based routing, storage and retrieval in network, compression technologies for WSN, Data aggregation technique. Case study- Detecting unauthorized activity using a sensor network, Target detection tracking, Habitat

monitoring, Environmental disaster monitoring, Practical implementation issues, IEEE 802.15.4 low rate WPAN, Operating System Design Issues. Simulation tools.

Text Books

1. *W. Dargie, C. Poellabauer, "Fundamentals of Wireless sensor networks -Theory and Practice", John Wiley & Sons Publication, 2010.*
2. *K. Sohraby, D.Minoli and T.Znati, "Wireless Sensor Network Technology Protocols and Applications", John Wiley & Sons, 2007.*
3. *HolgerKerl, Andreas Willig, "Protocols and Architectures for Wireless Sensor Network", John Wiley and Sons, 2005.*
4. *Feng Zhao, Leonidas Guibas, "Wireless Sensor Network", 1st Ed., Elsevier, 2004.*

Reference Books

1. *F.Zhao, L.Guibas, "Wireless Sensor Networks: an information processing approach", Elsevier publication, 2004.*
2. *C.S.Raghavendra Krishna, M.Sivalingam and Taribznati, "Wireless SensorNetworks", Springer publication, 2004.*
3. *H. Karl, A.willig, "Protocol and Architecture for Wireless Sensor Networks", John Wiley publication, Jan 2006.*
4. *Kazem, Sohraby, Daniel Minoli, TaiebZanti, "Wireless Sensor Network: Technology, Protocolsand Application", 1st Ed., John Wiley and Sons, 2007.*

Course Outcomes

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

1. Analyze the challenges and constraints of wireless sensor network and its subsystems.
2. Examine the physical layer specification, modulation and transceiver design considerations.
3. Compare and analyze the types of routing protocols and data aggregation techniques.
4. Identify the application areas and practical implementation issues.

Course Code	**:**	**IC 620**
Course Title	**:**	**Augmented Reality**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To study the fundamentals of Augmented Reality (AR) modeling and programming
2. To understand the tools and platforms used in the AR and Virtual Reality (VR).
3. To learn the principles and multidisciplinary features of virtual reality
4. To develop virtual environments and simulators

Course Content

Augmented reality and virtual reality - The historical development of AR and Virtual Reality: Scientific landmarks Computer Graphics, Real-time computer graphics, Flight simulation, Virtual environments, Requirements for AR and VR, benefits of AR and VR.

Hardware technologies for 3d user interfaces: Visual Displays Auditory Displays, Haptic Displays, Choosing Output Devices for 3D User Interfaces. Input device characteristics, Desktop input devices, Tracking Devices, 3D Mice, Special Purpose Input Devices, Direct Human Input, Home - Brewed Input Devices, Choosing Input Devices for 3D Interfaces.

Software technologies: Database - World Space, World Coordinate, World Environment, Objects - Geometry, Position / Orientation, Hierarchy, Bounding Volume, Scripts and other attributes, AR Environment - AR Database, Tessellated Data, LODs, Cullers and Occludes, Lights and Cameras, Scripts, Interaction - Simple, Feedback, Graphical User Interface, Control Panel, 2D Controls, Hardware Controls, Room / Stage / Area Descriptions, World Authoring and Playback, AR toolkits, Available software in the market.

3D interaction techniques - 3D Manipulation tasks, Manipulation Techniques and Input Devices, Interaction Techniques for 3D Manipulation, Design Guidelines - 3D Travel Tasks, Travel Techniques, Design Guidelines - Theoretical Foundations of Wayfinding, User Centered Wayfinding Support, Environment Centered Wayfinding Support, Evaluating Wayfinding Aids, Design Guidelines - System Control, Classification, Graphical Menus, Voice Commands, Gestural Commands, Tools, Multimodal System Control Techniques, Design Guidelines, Case Study: Mixing System Control Methods, Symbolic Input Tasks, symbolic Input Techniques, Design Guidelines, Beyond Text and Number entry.

Designing and developing 3d user interfaces - Strategies for Designing and Developing Guidelines and Evaluation-3D User Interfaces for the Real World, AR Interfaces as 3D Data Browsers, 3D Augmented Reality Interfaces, Augmented Surfaces and Tangible Interfaces, Agents in AR, Transitional AR-VR Interfaces - The future of 3D User Interfaces, Questions of

3D UI Technology, 3D Interaction Techniques, 3D UI Design and Development, 3D UI.

Evaluation and Other Issues. Engineering, Architecture, Education, Medicine, Entertainment, Science, Training.

Text Books

1. *Alan B Craig, William R Sherman and Jeffrey D Will, "Developing Virtual Reality Applications: Foundations of Effective Design", Morgan Kaufmann, 2009.*
2. *Gerard Jounghyun Kim, "Designing Virtual Systems: The Structured Approach", Springer Verlag London, 2005.*
3. *Doug A Bowman, Ernest Kuijff, Joseph J LaViola, Jr and Ivan Poupyrev, "3D User Interfaces, Theory and Practice", Addison Wesley, USA, 2004.*
4. *Oliver Bimber and Ramesh Raskar, "Spatial Augmented Reality: Meging Real and Virtual Worlds", CRC Press 2005.*

Reference Books

1. *Burdea, Grigore C and Philippe Coiffet, "Virtual Reality Technology", Wiley IEEE, 2003.*
2. *John Vince, "Virtual Reality Systems", Pearson Education, 1995.*
3. *Howard Rheingold, "Virtual Reality: The Revolutionary Technology and how it Promises to Transform Society", Simon and Schuster, 1991.*
4. *William R Sherman and Alan B Craig, "Understanding Virtual Reality: Interface, Application and Design (The Morgan Kaufmann Series in Computer Graphics)". Morgan Kaufmann Publishers, San Francisco, CA, 2002.*

Course Outcomes

On completion of this course, the students will be able to

1. Understand AR models and programs.
2. Develop 3D interaction techniques.
3. Design 3D user interface.
4. Apply AR and VR tools for various industrial applications.

Course Code	**:**	**IC 622**
Course Title	**:**	**Networked Control System**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To introduce different models of network control system.
2. To introduce different estimation techniques for network control system.
3. To introduce different network control system techniques.
4. To introduce different applications suited for network control systems**.**

Course Content

Stochastic process – Introduction to random variables, Expectations, Moments, stationary and non- stationary process.

Network models – Stochastic model, communication network constraints, packet delay, packet loss, uncertain observation, Markov chain-based model.

Estimation of networked control system – Observer for networked system, Kalman filter. Control strategies – Output feedback control, Predictive control.

Introduction to graph theory, Simulation of network control system, Application of network control system.

Text Books

1. *J. Medhi, "Stochastic Processes", 3rd Edition, New Age Science, 2009.*
2. *Jagannathan Sarangapani, Hao Xu, "Optimal Networked Control Systems with MATLAB",1st Edition, CRC press, Taylor and Francis group, 2016.*
3. *Xia Y., Fu M., Liu GP., "Analysis and Synthesis of Networked Control System, Lecture Notes in Control and Information Sciences", Springer-Verlag Berlin Heidelberg, 2011.*

Reference Books

1. *Anderson, B.D.O. and Moore J.B., "Optimal Filtering", Prentice-Hall, Englewood Cliffs, New Jersey, 1979.*
2. *K You, N Xiao, L Xie, "Analysis and Design of Networked Control System, Communications and Control Engineering", Springer London Heidelberg New York Dordrecht, 2015.*

3. *Srikant, Rayadurgam, Lei Ying, "Communication networks: an optimization, control, and stochastic networks perspective. Cambridge University Press,2013.*

Course Outcomes

On completion of this course, the students will be able to

1. Model the network control system with packet delay, loss and uncertain observation.
2. Design control system in the presence of quantization, network delay or packet loss.
3. Understand distributed estimation and control suited for network control system.
4. Develop simple application suited for networked control systems.

Course Code	**:**	**IC 624**
Course Title	**:**	**Cyber Security in Industrial Automation**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To introduce the knowledge of internet along with the changing trends in the cyber technologies.
2. Understand the various security threats and vulnerabilities of the cyber world keeping in line with the industrial trends.
3. Understand how web technology works, how web server capability is used in industry, and the security problems engendered by such use.
4. Locate web technologies where they can be used securely for industrial automation.

Course Content

Industrial Automation Fundamental Concepts - Industrial automation protocol summary-The Open System Interconnection (OSI) Model, The Transmission Control Protocol (TCP)/ Internet protocol (IP) Model, Object linking and embedding for process control, Open platform communication (OPC) Unified architecture, Modbus/ TCP Model, The distributed network protocol, Controller area network, Ethernet/ IP, Open safety protocol.

Information System Security Technology- Types and classes of attack, Policies, Standards, Guidelines and procedures, Malicious code and attacks, Firewalls, Cryptography, Attacks against cryptosystems.

Industrial Automation Culture versus Information Technology (IT) Paradigms- Considerations in adapting IT security methods to industrial automation, Threats, IT and industrial automation.

Risk Management for Industrial Automation- Risk management, ANSI/ISA-62443-2-1 (99.02.01)-2009 cyber security, Risk analysis, Addressing risk, NIST SP 800-39 Integrated enterprise risk management, Threats.

Industrial Automation Trends, Approaches, and Issues- Automation trends, Formal methods used to quantify and standardize, important concepts and applications -Information security continuous monitoring (ISCM) strategy, The Smart Grid Maturity Model (SGMM), Future smart grid issues and automation security issues.

Emerging Approaches to Industrial Automation Security- Internet of Things, Open platform communications unified architecture, Security and privacy, big data analytics and the industrial Internet of Things, The National Institute of Standards Technology (NIST) Cyber-Physical Systems (CPS) Framework, CPS and Cybersecurity, Critical Infrastructure security, Software-defined elements.

Text Books

1. *Ronald L. Krutz, "Industrial Automation and Control System Security Principles: Protecting the Critical Infrastructure", 2nd Edition, International Society of Automation, 2017.*
2. *David J. Teumim, "Industrial Network Security, Second Edition", International Society of Automation, 2010.*

Reference Books

1. *Lawrence M. Thompson and Tim Shaw, "Industrial Data Communications", Fifth Edition, International Society of Automation, 2015.*
2. *Dick Caro, "Automation Network Selection: A Reference Manual", 3rd Edition, Paperback, International Society of Automation, 2016.*

Course Outcomes

On completion of this course, the students will be able to

1. Get knowledge of security mechanisms, standards and state-of–the-art capabilities.
2. Design new systems and infrastructure level security solutions.
3. Develop and maintain new tools and technologies to enhance the security of applications in industrial automation.
4. Identify and solve different cyber security threats.

Course Code	**:**	**IC 626**
Course Title	**:**	**Rapid Prototyping**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To introduce about different classes of Rapid Prototyping (RP) systems.
2. To impart knowledge about applications of various RP processes.
3. To introduce about rapid tooling.
4. Understand about RP Technology selection.

Course Content

Introduction- Need for the compression in product development, History of Rapid Prototyping (RP) systems, Survey of applications, Growth of RP industry, Classification of RP systems.

Principle, process parameters, process details and applications of various RP processes - Stereo lithography systems, Laser Sintering, Fused Deposition Modeling, and Laminated Object.

Manufacturing, Solid Ground Curing, Laser Engineered Net Shaping, 3D Printing, Laser Melting, Cladding.

Rapid Tooling - Indirect rapid tooling, Direct rapid tooling, soft tooling Vs hard tooling, Rapid Manufacturing Process Optimization- Factors influencing accuracy, data preparation errors, part building errors, errors in finishing, influence of part build orientation.

Software for RP - STL files, Overview of solid view, Magics, mimics, magics communicator, etc., internet-based software, collaboration tools. RP Technology selection, Decision Making, Life Cycle Assessment of RP processes, Sustainability issues.

Text Books

1. *Prasad H and Badrinarayanan, K S, "Rapid Prototyping and Tooling", SPI-Pageturners, Bangalore, India, 2013.*
2. *Hilton P, Jacobs P F, "Rapid Tooling: Technologies and Industrial Applications", 1st Edition CRC press, 2000.*

Reference Books

1. *Pham D T and Dimov S S, "Rapid Manufacturing",* Springer*Verlag,2001.*
2. *Paul F Jacobs, "Stereo lithography and other RP&M Technologies", SME,1996.*
3. *Terry Wohlers, "Wohlers Report 2001", Wohlers Associates,2008.*

Course Outcomes

On completion of this course, the students will be able to

1. Understand the importance of time compression technologies
2. Select of appropriate technology for particular application.
3. Apply RP software packages
4. Recognize various types of rapid tooling.

Course Code	**:**	**IC 628**
Course Title	**:**	**Optimization Techniques**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objectives

1. To Introduce linear programming problem and to learn various methods to solve it.
2. To study essential optimization techniques and algorithms to solve one dimensional and multidimensional optimization problems.
3. To discuss the optimality conditions for the constrained and unconstrained optimization problems.
4. To model and solve Shortest-Route, allocation and production scheduling problems using dynamic programming.

Course Content

Linear programming – Formulation - Graphical and simplex methods - Big-M method - Two phase method - Dual simplex method - Primal Dual problems.

Unconstrained one-dimensional optimization techniques - Necessary and sufficient conditions – Unrestricted search methods - Fibonacci and Golden section method - Quadratic Interpolation methods, cubic interpolation.

Unconstrained multi-dimensional optimization techniques – Direct search methods – Random search – Pattern search - Descent methods - Steepest descent and conjugate gradient.

Constrained optimization Techniques - Necessary and sufficient conditions – Equality and inequality constraints - Kuhn-Tucker conditions - Gradient projection method - Cutting plane method - Penalty function method.

Dynamic programming - Principle of optimality - Recursive equation approach - Application to shortest route, cargo - loading, allocation and production schedule problems.

Text Books

1. *Rao,S.S., 'Engineering Optimization :Theory and Practice', New Age International, 3rd edition, 2018.*
2. *Taha, H.A.,'Operations Research –An Introduction', Pearson Education, 10th edition,2018.*
3. *Fox, R.L., 'Optimization methods for Engineering Design', Addison Wesley, 1981.*

Reference Books

1. *Mokhtar S. Bazaraa, Hanif D. Sherali and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley, 2013.*
2. *A. Ravindran, Don T. Phillips and James J. Solberg, Operations Research-Principles and Practice, John Wiley, 2014.*
3. *Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research, McGraw Hill, 2010.*
4. *Kanti Swarup, P.K. Gupta and Man Mohan, Operations Research, Sultan Chand, 2014.*

Course Outcomes

On completion of this course, the students will be able to

1. Understand formulation of linear programming-based problems and apply graphical and simplex methods.
2. Apply appropriate optimization technique and analyze unconstrained one-dimensional problems.
3. Apply appropriate optimization technique and analyze unconstrained multi-dimensional problems.
4. Appraise and evaluate constrained optimization problems related to Industrial Automation problems by appropriate methods.