SEMESTER I

21MC01 STATISTICAL INFERENCE AND MULTIVARIATE ANALYSIS

Vide Industrial Engineering 21MN01

21MC02 INTEGRATED PRODUCT DEVELOPMENT

3 1 0 4

PRODUCT LIFECYCLE MANAGEMENT: Definition, scope- PLM grid, objectives, Key Performance Indicators (KPIs), paradigm, characteristics, drivers; Phases of the product lifecycle, S- Curve, Bathtub curve; Product Data Management (PDM): Product data, structure, interaction in PLM; Significance of IoT and Big data in PLM; Case studies. (11+3)

CONCEPTUALIZATION AND PROTOTYPING: Customer needs, use-case, problem statement, bench marking and establishing engineering specifications; Idea generation: brainstorming, mind-map; Concept generation: C-sketch/6-3-5 method, morphological analysis; Concept selection and testing, product architecture, Prototyping: methods, types, case studies. (11+6)

PRODUCT DEVELOPMENT APPROACHES AND TOOLS: Challenges and constraints in product development; PESTEL analysis; SWOT analysis; Requirement Engineering; Requirement pyramid; Types of requirements; Quality Function Deployment (QFD); Product development methodologies; Theory of inventive problem solving (TRIZ); Establishing product function: FAST method; Failure Mode and Effects Analysis (FMEA): PFMEA, poka-yoke, online tools, case studies. (12+6)

SUSTENANCE ENGINEERING AND IPR: Maintenance: Activities, objectives, classification; Obsolescence Management: Objectives, mitigation measures, design for obsolescence**;** IPR: Types of IPR, Patentability criteria, steps in patenting, formulating claims, pursue application, issues and challenges. (11)

Total L: 45 + T: 15 = 60

REFERENCES:

1. Michael Grieves, “Product Lifecycle Management: Driving the Next Generation of Lean Thinking”, Tata McGraw Hill, First Edition, 2005.
2. John Stark, “Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation”, Springer, Fourth Edition, 2020.
3. Karl T. Ulrich, Steven D. Eppinger and Maria C. Yang “Product Design and Development”, Tata McGraw Hill, Seventh Edition, 2020.
4. Kevin Otto and Kristin Wood, “Product Design”, Pearson Education, 2003.
5. Chitale A. K. and Gupta R. C., “Product Design and Manufacturing”, Prentice Hall of India, Sixth Edition, 2014.
6. Nigel Cross, “Engineering Design Methods: Strategies for Product Design”, John Wiley and Sons, Fourth Edition, 2008

21MC03 BUSINESS OPERATIONS INTEGRATION

3 1 0 4

BUSINESS PROCESS: Processes, business functions, functional areas of operation, business process concepts, process view; Business operations, key terms – Engineering Change Note (ECN); Information flow: marketing and sales, supply chain management, accounting and finance, human resources; Functional area information system; Business Process Reengineering (BPR): background, elements, steps in BPR, challenges and best practices, business impact – case studies. (11+4)

ENTERPRISE RESOURCE PLANNING (ERP): Evolution of ERP, business benefits of ERP; ERP system: design process, architecture, features; Selecting an ERP system; ERP implementation factors; Hidden cost: cost benefit analysis, issues in customizing ERP systems; Training: Need, methods. (10+3)

ERP PACKAGE AND CASESTUDIES: Analysis of ERP packages, survey of Indian ERP packages - coverage, performance and cost; Extended ERP (ERP II)/advanced planning systems, business intelligent systems; IoT module for ERP system – case studies. (12+3)

ERP MODULES: Detailed analysis of ERP modules: Sales order processing, purchasing, production planning, manufacturing, financial accounting, human resource, simulation using typical ERP package; ERP case studies: Manufacturing and education domain. (12+5)

Total L: 45 + T: 15 = 60

REFERENCES:

1. David L. Olson, “Managerial Issues of Enterprise Resource Planning Systems”, Tata McGraw Hill Edition, 2017.
2. Mary Summer, “Enterprise Resource Planning”, Pearson Education Limited, 2014
3. Alexis Leon, “ERP Demystified”, Tata McGraw-Hill Publishing Company Limited, 2014.
4. Karl E. Kurbel, “Enterprise Resource Planning and Supply Chain Management”, Springer, 2013
5. Ellen F.Monk and Bret J.Wagner, “Concepts in Enterprise Resource Planning”, Course Technology, Cengage Learning,Fourth Edition, 2012.

21MC04 INDUSTRIAL AUTOMATION AND CONTROL

3 1 0 4

SENSORY SYSTEMS: Mechatronics system: Architecture, elements of mechatronics system, role of mechatronics in automation; Sensors and measurement systems in automation: Static and dynamic characteristics of sensors, transducers for measurement - displacement, strain, position, velocity, noise, flow, pressure, temperature, humidity, vibration, vision sensors; Selection of sensors for different applications. (12+4)

ACTUATORS, CONTROL VALVES AND FLUIDIC SYSTEM DESIGN: Actuators: Pneumatic, hydraulic, electrical, magnetostrictive and memory-metal actuators; Servo and stepper motors: Control valves: direction, pressure and flow proportional valves, control of servo valves, fluidic muscles actuators, shape memory alloys; Fluidic system design: Fluid power circuits – cascade, KV-map and step counter method; Fringe condition modules; Sizing of components in pneumatic and hydraulic systems; Analysis of hydraulic circuits. (13+4)

CONTROL SYSTEMS: Programmable Logic Controller (PLC): PLC ladder logic diagram, programming of PLC; Microcontrollers and microprocessors. (9+3)

REAL TIME INTERFACING: Data acquisition systems: Industry Interfacing devices, virtual instrumentation, interfacing of various sensors and actuators with PC; Condition monitoring; Adaptive control; Supervisory control and data acquisition (SCADA) systems; Human Machine Interface (HMI) systems;, Application case studies. (11+4)

Total L: 45 + T: 15 = 60

REFERENCES:

1. Sanjay Gupta and Joseph John, “Virtual Instrumentation using Lab VIEW”, Tata McGraw Hill Publications Co. Ltd., First Edition, 2017.
2. Mikell P. Groover, “Automation, Production Systems and Computer-Integrated Manufacturing”, Pearson Publications, Fourth Edition, 2016.
3. W Bolton, “Mechatronics - Electronic Control Systems in Mechanical and Electrical Engineering”, Pearson India., Sixth Edition, 2019.
4. DevdasShetty and Richard A. Kolk, “Mechatronics System Design”, Cengage Learning, Second Edition, 2012.
5. Anthony Esposito, “Fluid Power with Application”, Pearson Education India, Seventh Edition, 2013.

21MC05 SMART MANUFACTURING

3 0 0 3

CIM SYSTEMS: Architecture of CIM, Industry 4.0- Scope; FMS: Equipment, Tool management system, system layouts, Reconfigurable machines and systems. (11)

CAD/CAM/CAE: Role of CAD in design, types and applications of design models, need for reverse engineering, reverse engineering process, reverse engineering hardware and software, CNC - Tool path generation and simulation, CMM – history, economy, functions and operation method, additive manufacturing – need, applications and types. Case studies:3D Modelling of assemblies and systems, Simulation of machining processes using CAM packages, Reverse Engineering of engineering components. (12)

INTERNET OF THINGS: Applications, IoT data management requirements, Architecture of IoT, Technological challenges, RFID and Electronic Product Code (EPC) network, The web of things, Issues in implementation of IoT. (11)

VIRTUAL PROTOTYPING AND DIGITAL MANUFACTURING: History, Need for digital manufacturing, Virtual prototyping in product development, Virtual prototyping tools, Digital technologies, Impact on economy, Digital technology in manufacturing, Architecture of digital manufacturing system, Operation mode and applications of digital manufacturing. (11)

Total L: 45

REFERENCES:

1. Radhakrishnan P, Subramanyan S. and Raju V., “CAD/CAM/CIM”, New Age International Ltd., Fourth Edition, 2018.
2. Adrian McEwan and Hakim Cassimally, “Designing the Internet of Things”, Wiley, 2013.
3. Frank W. Liou, “Rapid Prototyping and Engineering Application – A Toolbox for Prototype Developments”, CRC Press, 2007.
4. Vinesh Raja and Kiran J. Fernandes, “Reverse Engineering-An Industrial Perspective”, Springer-Verlag, 2008.
5. Gerard Jounghyun Kim, “Designing Virtual Systems: The Structured Approach”, Springer, 2005.

21MC06 Research Methodology and IPR

vide Automotive Engineering 21AE06

2 0 0 2

21MC72 AUDIT COURSE I

vide Automotive Engineering 21AE72

21MC51 SENSOR INTERFACE AND ROBOTICS LABORATORY

0 0 4 2

In this course, students will be provided with an orientation on the following topics for a duration of 12-16 hours. Each student is expected to perform a case study by formulating and completing an activity of interest derived from the orientation under the guidance of faculty. The details expected in the final report to be submitted at the end of the semester are: Problem definition, literature review, objectives, methodology, analysis and interpretation of results and conclusions.

TOPICS FOR ORIENTATION

1. Calibration of sensors using virtual instrumentation software.
2. Sensor interface using virtual instrumentation software.
3. Control of actuators using virtual instrumentation software.
4. Sensor interfacing and programming of a typical pick and place robot.
5. System control using PI and PID controllers.

CASE STUDY

Interfacing and integration of sensors/ actuators for development of mechatronic systems for industrial applications.

Total P: 60

REFERENCES:

1. Sensor Interface and Robotics Laboratory Manual prepared by Department of Mechanical Engineering, PSG College of Technology.
2. Frank Lamb, “Industrial Automation Hands On”, McGraw Hill Book Company,2013
3. Terry L. M. Bartelt, “Industrial Automated Systems: Instrumentation and Motion Control”, Cengage Learning, New Delhi, 2011

21MC52 MANUFACTURING SIMULATION AND IoT LABORATORY

0 0 4 2

In this course, students will be provided with an orientation on the following topics for duration of 12-16 hours. Each student is expected to perform a case study by formulating and completing an activity of interest derived from the orientation under the guidance of faculty. The details expected in the final report to be submitted at the end of the semester are: Problem definition, literature review, objectives, methodology, analysis and interpretation of results and conclusions.

TOPICS FOR ORIENTATION

1. Product/Process layout simulation and performance analysis.
2. Logistics simulation and inventory analysis.
3. Measurement systems analysis and process capability analysis.
4. Machine tool condition monitoring using IoT devices.
5. Sensor data analytics of IoT devices.

CASE-STUDY

Visualization of bottle-necks in a manufacturing plant and machine monitoring using IoT.

Total P: 60

REFERENCES:

1. Manufacturing Simulation and IoT Laboratory Manual, Department of Mechanical Engineering, PSG College of Technology.
2. Malcolm Beaverstock, Allen Greenwood, William Nordgren,“Applied Simulation: Modeling and Analysis Using FlexSim", BookBaby, Fifth Edition, 2018

SEMESTER II

21MC07 INDUSTRIAL ROBOTICS

3 0 0 3

ROBOTICS, DRIVES AND CONTROLLERS: Robotics: Evolution, laws of robotics, anatomy of robot, classification of robots, Roboticdrive systems: electrical, hydraulic and pneumatic drives - characteristics of actuating systems; Robot controllers: motion control of robots: PI, PID. (12)

SENSORS FOR ROBOTS: Characteristics and selection of sensor: Position sensors, velocity sensors, acceleration sensors, force and pressure sensors, torque sensors, micro switches, light and infrared sensors, touch and tactile sensors, proximity and range sensors, sniff sensors, voice recognition devices, voice synthesizers. (10)

TRANSFORMATIONS, KINEMATICS AND ROBOT PROGRAMMING: Co-ordinate reference frames, homogeneous transformations, the forward and inverse kinematics, motion generation, manipulator dynamics, D.H Parameters, D.H matrices; Robot Programming: Programming methods. (13)

ROBOT CELL LAYOUT AND INSTALLATION: Robot cell layout, Classification, considerations in work cell design, safety monitoring; Robot installation: Feasibility of the robotization plan, evaluation strategies, planning for robot installation; Case studies. (10)

Total L: 45

REFERENCES:

1. Nicholas Odrey, Mitchell Weiss, Mikell Groover, Roger Nagel, Ashish Dutta, "Industrial Robotics: Technology, Programming and Applications**",** Tata McGraw Hill Education Pvt.ltd.", Second Edition, 2017.
2. Deb S.R. and Sankha Deb, "Robotics Technology and Flexible Automation", Tata McGraw Hill Education Pvt. Ltd., Second Edition, 2017.
3. Saeed B. Niku, "Introduction to Robotics Analysis, Systems, Applications", Pearson education (Singapore) Pvt. Ltd., Second Edition, 2017.
4. Richard D. Klafter, Thomas A. Chmielewski, Michael Negin, "Robotic Engineering: An Integrated Approach", Prentice hall Pvt. Ltd., Eastern Economy Edition, 2009.

21MC08 COMPUTER CONTROLLED MACHINE TOOLS

3 1 0 4

CONSTRUCTIONAL FEATURES OF CNC MACHINE TOOLS: Role of CNC machine tools in CAM, characteristics, selection criteria; Machining centers: features, Automatic Tool Changers (ATC), tool magazines, Automatic Pallet Changers (APC), attachments; Precision machine tools: hydrostatic guideways, hydrostatic spindle, encoders. (12)

CNC PART PROGRAMMING: Axes definition, datum, structure of program, G and M functions, motion types, tool length compensation, cutter radius compensation, tool wear compensation, canned cycles, sub-programming, mirroring, scaling; Part program examples: turning, milling, drilling; Automatically Programmed Tool (APT); Simulation of part programs – case-study. (11+5)

CNC CONTROL SYSTEMS: Structure of CNC system, open loop and closed loop systems, Adaptive control systems: adaptive control with constraints, adaptive control with optimization; microprocessor based CNC systems, Interpolators: linear interpolation, circular interpolation; DDA algorithm and Bresenham algorithm, calculation of Basic Length Unit (BLU), pulses, pulse frequency; Open source CNC controllers- case-study. (11+5)

CALIBRATION AND CONDITION MONITORING OF CNC MACHINE TOOLS: Precision and accuracy, machine specifications, Calibration, ISO standards, geometric accuracy of machines, repeatability of positioning CNC machine tools, determination of thermal effects, circular test for CNC machine tools, determination of noise emission, axes of rotation, determination of vibration levels; Measurement of uncertainty, tool wear monitoring methods, Compensation: backlash, pitch error, thermal error. (11+5)

Total L:45 + T:15 =60

REFERENCES:

1. Radhakrishnan P., "Computer Numerical Control (CNC) Machines", New Central Book Agency, 2015.
2. YoramKoren, "Computer Control of Manufacturing Systems", Tata McGraw Hill Book Co., 2017.
3. Peter Smid, "CNC Programming Handbook", Industrial Press, 3rd Edition, Inc, 2015
4. ISO standards ISO-230 series, 2015
5. Alan Overby,"CNC Machining Handbook: Building, Programming, and Implementation", McGraw Hill Education TAB, 2010

21MC82 AUDIT COURSE II

vide Automotive Engineering 21AE82

21MC61 CAD / CAM / CAE LABORATORY

0 0 4 2

In this course, students will be provided with an orientation on the following topics for a duration of 12-16 hours. Each student is expected to perform a case study by formulating and completing an activity of interest derived from the orientation under the guidance of faculty. The details expected in the final report to be submitted at the end of the semester are: Problem definition, literature review, objectives, methodology, analysis and interpretation of results and conclusions.

TOPICS FOR ORIENTATION

1. Part modelling and preparation of production drawings using CAD software.
2. Product assembly using CAD software.
3. Cutter location data file generation.

4. Robot kinematic analysis.
5. Multibody dynamics of robots.

CASE-STUDY:
Modeling, assembly and multibody dynamics of typical industrial robots with relevant tool path generation for manufacturing.

Total P: 60

REFERENCES:
1. CAD/CAM/CAE Laboratory Manual, Department of Mechanical Engineering, PSG college of Technology.
2. Sham Tickoo “PTC Creo - Parametric 3.0 for Designers”, Cadcim Technologies, 2015
3. Reza N. Jazar, "Theory of Applied Robotics: Kinematics, Dynamics, and Control", Springer, Second Edition, 2016

21MC62 AUTOMATED MANUFACTURING SYSTEMS LABORATORY

0 0 4 2

In this course, students will be provided with an orientation on the following topics for a duration of 12-16 hours. Each student is expected to perform a case study by formulating and completing an activity of interest derived from the orientation under the guidance of faculty. The details expected in the final report to be submitted at the end of the semester are: Problem definition, literature review, objectives, methodology, analysis and interpretation of results and conclusions.

TOPICS FOR ORIENTATION
1. Process planning and selection of parameters for typical industrial components.
2. CNC part programming and simulation.
3. Part manufacturing using CNC machines.
4. Automated inspection of components using image processing.

CASE-STUDY:
Manufacturing and inspection of typical industrial components.

Total P: 60

REFERENCES:
1. Automated Manufacturing Systems Laboratory Manual, Department of Mechanical Engineering, PSG college of Technology.
2. Peter Smid, “CNC Setup for Milling and Turning: Mastering CNC Control Systems”, Industrial Press Inc., 2010

21MC63 INDUSTRIAL VISIT AND TECHNICAL SEMINAR

vide Automotive Engineering 21AE63

SEMESTER – III

21MC71 PROJECT WORK – I

vide Automotive Engineering 21AE71

SEMESTER – IV

21MC81 PROJECT WORK – II

Vide Automotive Engineering 21AE81

PROFESSIONAL ELECTIVES

21MC21 DATA STRUCTURES AND COMPUTER PROGRAMMING

3 0 0 3

DATA STRUCTURES, ARRAYS AND LINKED LISTS: Data structures: Definition, types of data structures, abstract data types, algorithms; Arrays: array representation, algorithms - linear and binary search, insertion and bubble sort; Linked lists: linked list representation, polynomial addition and sparse matrices, algorithms (11)

STACKS, QUEUES AND TREES: Stacks: representation, expression handling, algorithms; Queues: Queue representation, types of queues – circular queue, dequeue, priority queue, algorithms; Trees: Terminologies, Binary trees – types, representation, binary tree searching operations, binary heaps, heap sort, multi-way search trees, algorithms. (10)

OBJECT ORIENTED PROGRAMMING: Review of object oriented programming language-C++: Concepts of OOP; Functions: function prototyping, call by reference, return by reference, overloading functions, case study; Classes and objects: creation of classes, creation and data allocation for objects, arrays of objects, member functions of classes, inheritance – defining derived classes and single inheritance, algorithms. (12)

PYTHON PROGRAMMING: Data types, functions, loop structures, decision structures, classes, objects and graphics, algorithms. . (12)

Total L: 45

REFERENCES:

1. Jean-Paul Tremblay and Paul G. Sorenson, “An Introduction to Data Structures with Applications”, McGraw Hill Education, Second Edition, 2017.
2. Venkatesan R. and Lovelyn Rose S., “Data Structures”, Wiley; Second Edition, 2019.
3. Mark Allen Weiss, “Data Structures and Algorithm Analysis in C++”, Third Edition, Pearson Education, 2014.
4. Bjarne Stroustrup, “The C++ Programming Language”, Addison Wesley, 2013.
5. Alfred V. Aho Jeffrey D. Ullman John E. Hopcroft, “Data Structures and Algorithms”, Pearson Education, 2002.
6. John Zelle, “Python Programming: An Introduction to Computer Science”, Franklin, Beedle & Associates Inc, 2020

21MC22 ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

3 0 0 3

SEARCH ALGORITHMS: Agents and environments, structure of agents, problem-solving agents, formulating problems, general tree-search and graph-search algorithms, Infrastructure for search algorithms, Measuring problem-solving performance; Uninformed search strategies: Breadth-first search, uniform-cost search, depth-first search, depth-limited search, iterative deepening depth-first search, bidirectional search; Informed search strategies: Greedy best-first search, A* search, Recursive best-first search (RBFS), Hill-climbing search; Knowledge representation; Case studies for practical problems with programming. (12)

META-HEURISTIC ALGORITHMS: Genetic algorithms, simulated annealing, tabu search, ant colony optimization, particle swarm optimization, differential evolution, harmony search, bee algorithms; Case studies for practical problems with programming. (12)

MACHINE LEARNING TECHNIQUES: Supervised learning: classification - support vector machines, linear discriminant analysis, naive bayes k-nearest neighbor, Regression - Linear Regression, generalized linear model, decision trees; Unsupervised learning: Clustering- k-Means clustering, hierarchical clustering,apriori algorithm; Case studies for practical problems with programming. (11)

DEEP LEARNING WITH NEURAL NETWORKS: Nodes and layers of neural network, training of single layer neural networks, training of multi-layer networks, architectures of deep networks, building deep networks; Case studies for practical problems with programming. (10)

Total L: 45

REFERENCES:

1. Omid Bozorg-Haddad,Mohammad Solgi, Hugo A. Loáiciga, “Meta-heuristic and Evolutionary Algorithms for Engineering Optimization”, Wiley; FirstEdition, 2017
2. Phil Kim, “MATLAB Deep Learning: With Machine Learning, Neural Networks and Artificial Intelligence”, Apress, First Edition, 2017
3. Josh Patterson, “Deep Learning: A Practitioner's Approach”, O'Reilly; First edition, 2017
4. Stuart Russell and Peter Norvig, “Artificial Intelligence: A Modern Approach”, Pearson Education Limited, England, Third edition, 2016.
5. Ethem Alpaydm, “Introduction to Machine Learning”, PHI Learning Pvt. Ltd, Third Edition, 2015
6. Peter Harrington, “Machine Learning in Action”, Manning Publications Co, 2012

21MC23 VIRTUAL MANUFACTURING

3 0 0 3

VIRTUAL REALITY AND VIRTUAL MANUFACTURING: Virtual reality: overview, four I’s of VR, components of VR system; Augmented reality: overview, virtual reality versus augmented reality; Virtual manufacturing: physical prototype versus virtual prototype, virtual environment, virtual machine, virtual factory. (9)

HARDWARE AND SOFTWARE FOR VIRTUAL MANUFACTURING: Input devices: trackers, navigation and manipulation interfaces, gesture interfaces; Output devices: graphics displays, sound displays, haptic feedback; VR toolkits: VRPN, VR programming; multi modal interaction, simulators. (12)

MODELING AND SIMULATION: Geometric modeling: virtual object shapes, visual appearance, object hierarchies, model management, LOD; Simulation: physical modeling, bounding volumes, handling collision detection; Response: transformation, force computation, surface deformation, haptic texturing. (12)

VALIDATION AND ANALYSIS: Design validation, verification by simulation, analysis of manufacturing processes, material handling and storage system, process layout, plant maintenance. (12)

Total L: 45

REFERENCES:

1. Grigore C. Burdea, and Philippe Coiffet, “Virtual Reality Technology”, Wiley; Second Edition, 2006
2. Gerard Jounghyun Kim, “Designing Virtual Systems: The Structured Approach”, Springer, 2005
3. Timothy Jung and M. Claudia Tom Dieck,“Augmented Reality and Virtual Reality: Empowering Human, Place and Business”, Springer, 2018
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, 2018.
5. Oliver Bimber and Ramesh Raskar, “Spatial Augmented Reality: Merging Real and Virtual Worlds”, A K Peters / CRC Press, 2005.

21MC24 AUTOMATIC CONTROL SYSTEMS

3 0 0 3

CONTROL SYSTEMS: Components, open loop and closed loop systems; Transfer function: modeling of physical systems, mechanical systems, translational and rotational systems, thermal, hydraulic systems and electrical systems, DC servomotor, AC servomotor, potentiometer, tacho-generator; Stepper motor: Block diagram - reduction techniques, signal flow graph – Mason’s gain formula. (11)

TIME DOMAIN ANALYSIS: Continuous time signals, standard test signals; Classification of continuous time systems: Linear-nonlinear, Time variant, Time invariant, Static – Dynamic; Time response of second order system; Time domain specifications; Steady state error constants; Generalized error series; Introduction to P, PI and PID modes of feedback control. (12)

STATE SPACE ANALYSIS: Limitations of conventional control theory; Concepts of state, state variables and state model; state model for linear time invariant systems; Introduction to state space representation using physical; Phase and canonical variables; State equations; Transfer function from the state model; Solutions of the state equations; State transition matrix; Concepts of controllability and observability, System stability; Basic concepts of stability. (11)

FREQUENCY RESPONSE OF SYSTEMS: Frequency domain specifications; Estimation for second order systems; Correlation between time and frequency domain specifications for second order systems; Frequency domain analysis; Bode plot: determination of transfer function from bode plot. (11)

Total L: 45

REFERENCES:

1. Smarajit Ghosh, “Control Systems Theory and Applications”, Pearson Education, Second Edition, New Delhi, 2012.
2. Norman S. Nise, “Nise's Control Systems Engineering”, Wiley & Sons, India Special Edition, 2018.
3. Richard C. Dorf and Robert H. Bishop, "Modern Control Systems”, Pearson Education India, Twelfth Edition, 2013.
4. S. Palani, “Control Systems Engineering”, Mc-Graw Hill Education Pvt. Ltd, Second Edition, New Delhi, 2009.
5. Ogata K, "Modern Control Engineering", Pearson Education, Fifth Edition, New Delhi, 2015.
6. Nagrath I. J, and Gopal M, 'Control Systems Engineering”, New Age International Pvt. Ltd., Sixth Edition, 2018.

21MC25 INDUSTRIAL INTERNET OF THINGS

3 0 0 3

INTERNET OF THINGS (IoT) ARCHITECTURE: Concepts: IoT, Industrial IoT (IIoT), M2M, WoT, IoT components; Sensing: types of sensors, functions; Actuation: types of actuators, functions; Wi-Fi: Types, wireless security; IoT Architecture; Advancements in IoT; Use cases. (10)

COMMUNICATION AND NETWORKING PROTOCOLS: Internet Communication: TCP/IP, IP Address, MAC Address; Wireless sensor networks: types, manet; Protocols: 802.15.4, ZigBee, Lora, TCP, UDP, 6LoWPAN, RFID, NFC, Bluetooth, ZWave, 3G, 4G, 5G; IoT Network configurations; Use cases. (12)

ELECTRONIC PROTOTYPING: Prototype production (coding): Open source, closed source; Prototype embedded system: Open source, self product, wired, wireless; Overview of basic programming: Arduino, python; Prototyping IoT projects: Arduino, raspberry Pi; IoT Case studies; IoT exercises (wired): Arduino, Raspberry Pi. (12)

IoT DATA ANALYTICS: Data processing: MQTT, MQTT components and methods, cloud computing; Data handling: Types of data, Big Data; Data analytics: Types, data analytics life-cycle; Streaming data analytics: hive, hadoop; Data security: Data protection, challenges; IoT exercises (MQTT/cloud): Arduino, Raspberry Pi. (11)

Total L: 45

REFERENCES:

1. Alasdair Gilchrist , “Industry 4.0: The Industrial Internet of Things”, Apress; First Edition, 2019
2. HwaiyuGeng, "Internet of Things and Data Analytics Handbook", Wiley-Blackwell, 2017
3. AgusKurniawan, "Smart Internet of Things Projects", Packt Publishing Limited, 2016
4. Adrian McEwen and Hakim Cassimally, “Designing the Internet of Things”, John Wiley & Sons Ltd., UK, 2014.

21MC26 ADDITIVE MANUFACTURING

3 0 0 3

ALGORITHMS FOR ADDITIVE MANUFACTURING (AM): Generalized AM process chain, classification of AM processes, comparison of AM with CNC machining; Stages in AM, STL files: Format, errors and repairs, algorithm; Slicing algorithms- tool path generation; Effect of invalid models; Software used for AM. (11)

AM PROCESS FOR POLYMERS: Vat photo polymerization processes: vector scan, mask projection and two photon approach, materials, scan patterns; Sheet lamination processes: Bond-Then-Form processes, Form-Then-Bond processes, materials; Fused Deposition Modeling (FDM), process parameters, influence of process parameters in the mechanical properties of prototype; Support material removal methods; Case studies on automobile and medical applications. (12)

METAL ADDITIVE MANUFACTURING: Ultrasonic Additive manufacturing: Working principle, process parameters, microstructures and mechanical properties; Powder bed fusion (PBF) processes: Direct metal laser sintering (DMLS), Electron beam melting (EBM), Selective heat sintering (SHS), Selective laser melting (SLM) and Selective laser sintering (SLS); PBF processes challenges, process parameters, powder handling systems, characteristics; Post-processing technique: hot isostatic pressing (HIP); Case studies for aerospace applications. (12)

DESIGN FOR AM: AM unique capabilities; Exploring design freedoms: Part consolidation and redesign, hierarchical structures, industrial design applications; CAD Tools for AM: Challenges for CAD, promising CAD technologies; Case studies on online platforms to convert ideas into 3D products. (10)

Total L: 45

REFERENCES:

1. Ian Gibson, David Rosen, Brent Stucker, “Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing”, Second Edition, Springer, 2016.
2. Andreas Gebhardt, “Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing”, Hanser, 2012.
3. D.T Pham, S.S. Dimov, “Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling”, Springer Science & Business Media, 2012
4. Chee Kai Chua, Kah Fai Leong, Chu Sing Lim, “Rapid Prototyping: Principles and Applications”, World Scientific, 2010.

21MC27 ADVANCED MANUFACTURING PROCESSES

3 0 0 3

MECHANICAL ENERGY PROCESSES: Ultrasonic machining (USM), Abrasive jet machining (AJM), Water jet machining (WJM), Abrasive water jet machining (AWJM), Abrasive flow machining (AFM) and Magnetic abrasive finishing (MAF); Process principles, equipment, effect of process parameters, Mathematical models for MRR. (12)

THERMAL, THERMO-ELECTRICAL AND CHEMICAL MACHINING ENERGY PROCESSES: Electron beam machining (EBM), Plasma arc machining (PAM), Laser beam machining (LBM); Electrical discharge machining (EDM), Spark and Wire EDM; Electro chemical machining (ECM); Process principles, equipment, effect of process parameters. (12)

HYBRID MACHINING PROCESSES: Classification: Vibration assisted EDM, Ultrasonic assisted ECM; Laser assisted ECM, Laser assisted EDM; Magnetic field assisted EDM, Magnetic field assisted AFM; Electric Discharge Diamond Grinding, Electrochemical Discharge Machining, Electrochemical Grinding, Electrochemical Discharge Grinding. (10)

MICRO MACHINING AND NANO FABRICATION: Micromachining: principle, chip formation-size effect in micromachining, micro-turning, micro-milling, micro-drilling, micro EDM, Micro-wire EDM, micro ECM, laser micro-machining; Process principles, equipment, effect of process parameters. Nano fabrication: LIGA, ion beam etching, molecular manufacturing techniques, nano machining techniques, sub micron lithographic technique. (11)

Total L: 45

REFERENCES:

1. Vijay K.Jain, “Advanced Machining Processes”, Allied Publishers, 2017
2. Gary F Benedict, “Nontraditional Manufacturing Process”, CRC Press, 2015
3. Pandey P C, "Modern Machining Systems", Tata McGraw Hill Publication, 2012
4. Vijay K.Jain, “Introduction to micro-machining”, Narosa, 2010
5. Madou, M.J., “Fundamentals of Microfabrication: The Science of Miniaturization”, Second Edition, CRC Press, Third Edition, 2006
6. Hassan Abdel-Gawad El-Hofy, “Advanced Machining Processes: Non-traditional and Hybrid Machining Processes”, McGraw-Hill Education, First Edition, 2005

21MC28 METROLOGY AND AUTOMATED INSPECTION

3 0 0 3

MEASUREMENT CONCEPTS AND SURFACE FINISH MEASUREMENTS: Definition, standards of measurement, errors in measurement, error analysis and classification, rules for estimating error, sources of errors, Interchangeability and selective assembly, accuracy and precision, calibration of instruments, types of surface texture, surface roughness measurement methods-comparison, Profilometer, 3D surface roughness measurement – Instruments. (13)

INTERFEROMETRY & LASER METROLOGY: Review of Interferometry, principles of light interference, types of Interferometers, Interferometer measurement and calibration with laser interferometer, laser micrometer, laser scanning gauge, laser interferometry. (10)

MACHINE VISION: Commercial machine vision systems, advanced machine vision for Industry 4.0 using AI for Inspection using smart cameras, overview of image acquisition and digitizing thresholding, edge detection, feature extraction and interpretation**.** (12)

ADVANCED INSPECTION SYSTEM : Tool Makers Microscope, Coordinate Measuring Machine (CMM), applications, non contact and in-process inspection, case studies: Ultrasonic sensors for automated inspection, automated inspection for packaging product, automatic inspection of engine block. multi gauging, robotic testing and inspection,automobile body gauging. (10)

TOTAL L: 45

REFERENCES:

1. Gupta, I.C, “A Text Book of Engineering Metrology”, Dhanpat Rai and Sons, 2018.
2. Rajput, R. K., “Engineering Metrology and Instrumentations”, Kataria & Sons Publishers, Fifth Edition, 2013.
3. Graham T. Smith., “Industrial Metrology: Surfaces and Roundness”, Springer London Ltd, 2010.
4. Milan Sonka, Vaclav Hlavac and Roger Boyle., “Image Processing, Analysis, and Machine Vision”, Cengage-Engineering, Third Edition, 2007.
5. Alciatore, D.G. and Histand, M. B., “Introduction to Mechatronics and Measurement Systems”, McGraw-Hill, Third Edition, 2007.
6. Stanley, L.R. and Richard, K.M., “Automated inspection and quality assurance”, CRC Press, First Edition, 1989.

21MC29 SHEET METAL CUTTING AND BENDING TECHNOLOGIES

3 0 0 3

SHEET METAL CUTTING TECHNIQUES: Growth of sheet metal industry, terminology, blanking operations, selection of punch presses, calculation of tonnage, cutting operations, Selection of cutting processes and machinery: Laser cutting, water-jet cutting, plasma cutting, oxy-fuel cutting; Specifications, selection process parameters; (11)

NESTING PROCESS: Concepts, factors to be considered, objectives, strategies, evaluation of different layout generation methods, Nesting algorithms: Heuristics, expert systems, Artificial Intelligent methods; Case studies with CAM packages. (11)

SHEET METAL BENDING TECHNIQUES: Terminology, types of bending operations, types of press brakes, constructional features, specifications, press brake tooling, types of punches, selection of die, development of unfold. (12)

SHEET METAL BENDING PLAN AND DESIGN CONSIDERATIONS: Bending sequence generation methods, tooling stages and setup, back-gauge positioning, collision check methods, optimization concepts, software packages, design considerations, product handling methods, protection and packaging methods. (11)

Total L: 45

REFERENCES:

1. David J. Gingery, “Sheet Metal Technology”, David J Gingery Publishing, First Edition, 2016.
2. Vukota Boljanovic, “Sheet Metal Forming Processes and Die Design”, Industrial Press Inc., Second Edition(Revised), 2014.
3. Ramesh Babu A and Ramesh Babu N, “Effective Nesting of Complex Two Dimensional Shapes - Genetic and Heuristic Approaches”, LAP LAMBERT Academic Publishing, GMBH & Co. Germany, 2012.
4. Steve D. Benson, “Press Brake Technology: A Guide to Precision Sheet Metal Bending”, Society of Manufacturing Engineers, First edition, 1997
5. Amada Sheet Metal Working Research Association “Bending Technique: New Knowhow on Sheet-metal Fabrication”, Machinist Publications,1981.

21MC30 MANUFACTURING SYSTEMS DESIGN AND ANALYSIS

3 0 0 3

MANUFACTURING SYSTEMS DESIGN: Types and principles of manufacturing systems, types and uses of manufacturing models, Assembly lines - reliable serial systems; Approaches to line balancing – largest candidate rule, Kilbridge and Wester method, ranked positional weight heuristic, COMSOAL, sequencing mixed models; Transfer lines and general serial systems – paced lines with and without buffers, unpaced lines. (10)

FACILITY LAYOUTS AND FLEXIBLE MANUFACTURING SYSTEMS: Types of Facility layouts, advantages, limitations, systematic layout planning, layout design procedures; Cellular systems -Group technology, coding schemes, assigning machines to groups, production flow analysis, binary ordering algorithm, single pass heuristic, similarity coefficient method; System components – system design, scheduling and control – flow shop scheduling, job shop scheduling; Flexible inspection system. (12)

ANAYSIS OF AUTOMATED MATERIAL HANDLING AND STORAGE: Material handling principles, Equipment's, Conveyor types and analysis, Automated guided vehicles and analysis; Warehousing – Analysis of Automated storage and retrieval systems, Carousal storage systems; Introduction to material handling and storage software. (11)

ANALYSIS OF AUTOMATED MANUFACTURING SYSTEMS: Queuing models – notations, performance measures, M/M/1 queue, M/M/s queue, batch arrival queuing systems, queues with breakdowns; Queuing networks – open and closed networks, central server model; Petrinet modeling - Classical Petrinets, transformation firing and reachability, reachability graphs, representation schemes, Modeling of manufacturing systems. (12)

Total L: 45

REFERENCES:

1. Ronald G. Askin, "Modeling and Analysis of Manufacturing Systems", John Wiley and Sons, First Edition, 1993.
2. Mikell P. Groover, "Automation, Production Systems, and Computer-Integrated Manufacturing", Pearson, Fifth Edition, 2018
3. Viswanatham .N and Narahari Y "Performance Modeling of Automated Manufacturing Systems", Prentice Hall Inc., 1994.
4. Mengchu Zhou, "Modeling, Simulation and Control of Flexible Manufacturing Systems: A Petri Net Approach", World Scientific Publishing Company Pvt. Ltd., 2000
5. Brandimarte P and Villa A, "Modeling Manufacturing Systems", Springer, First Edition (reprint), 2010

21MC31 PRODUCTION TOOLING AND COST ESTIMATION

3 0 0 3

TOOLING SELECTION: Interpretation of blue prints:Dimensions, geometrical features, surface finish, tolerances; Selection of machines: machine capability- parameters to be considered; Tooling selection: Factors, specifications, classification, tools – cutting tools,finishing tools, tool holders. (10)

DEVELOPMENT OF PROCESS PLANAND SELECTION OF WORK HOLDING DEVICES: Material evaluation, process selection, operations sequencing. Jigs and Fixtures: Degrees of freedom, principles of location and clamping, elements of jigs and fixtures, classification of jigs and fixtures, conceptual design of jigs and fixtures, modular fixtures for assembly and inspection. (15)

COSTING: Elements of cost:Material cost, labor cost, capital cost – space, power, machine, tools, dies, fixtures, overhead cost, sales cost; Types of costing: Batch costing, contract costing, departmental costing and process costing; Cost classification: Direct, indirect - capital depreciation, factory overheads, administrative overheads, sales overheads, distribution overheads. + (10)

COST CALCULATION: Calculation of machine hour rate- calculation of machining time, calculation of labor hour rate, Calculation of material cost- raw material, material handling cost, procurement cost; Calculation of cost for assembly, inspection and testing, calculation of overhead cost- material, labor, administrative and distribution, software tools for cost estimation. (10)

Total L: 45

REFERENCES:

1. Mikell. P .Groover, "Fundamentals of Modern Manufacturing – Materials Processes and Systems", John Wiley and Sons, Seventh Edition, 2020
2. SC Sharma & TR Banga, "Mechanical Estimating and Costing – including contracting", Khanna Publishers Pvt. Ltd., 2015
3. SME, "Manufacturing Engineers HandBook", Mc-Graw Hill, Second Edition, 2015
4. Riggs, J.L ., Dedworth, Bedworth, D.B., Randhawa, S.U, "Engineering Economics", McGraw Hill International Edition, Fourth Edition, 2004
5. Narang CBS and Kumar V, "Production and Costing", Khanna Publishers, 2005
6. Peter Scallan, "Process Planning: The Design/Manufacture Interface", Butterworth Heinemann, 2003

21MC32 PRODUCT DESIGN FOR MANUFACTURE AND ASSEMBLY

3 0 0 3

TOLERANCE AND PROCESS CAPABILITY ANALYSIS: Rules and methodologies used to design components for manual, automatic and flexible assembly, DFA index, poka-yoke, six sigma concepts; Cumulative effect of tolerances; Process capability, process capability metrics, Cp, Cpk, cost aspects. (12)

GEOMETRIC TOLERANCING AND SELECTIVE ASSEMBLY: Limits and fits, surface finish, review of relationship between attainable tolerance grades and different machining processes; Geometric tolerancing for manufacture as per Indian standards and ASME Y 14.5-2018 standard; Interchangeable part manufacture; Selective assembly – Model-I: group tolerances of mating

parts equal; Model-II: total and group tolerances of shaft equal; Control of axial play - introducing secondary machining operations, laminated shims, selective assembly, examples. (10)

TRUE POSITION THEORY AND DATUM SYSTEMS: True position theory - comparison between coordinate and conventional method of feature location, true position tolerancing, virtual size concept, floating and fixed fasteners, projected tolerance zone, zero true position tolerance; Functional gauges for inspection; Degrees of freedom, grouped datum systems - different types, two and three mutually perpendicular grouped datum planes; Grouped datum system with spigot and recess, pin and hole; Grouped datum system with spigot - recess pair and tongue - slot pair - computation of translational and rotational accuracy, geometric analysis and applications. (12)

DESIGN FOR MANUFACTURING PROCESSES: Design for sand casting: Design rules, parting line considerations, core requirements, redesigning cast members using weldments, case-studies; Design guidelines for welding, case-studies; Design for machining: Standardization, redesign of components to facilitate machining, case-studies; Design for sheet metal working: Design rules-blanking, lancing, forming, bending, stability, geometry, aesthetics, case-studies; Design for injection moulding: Guidelines, material selection, clamping force, geometry, tolerances, case-studies. (11)

Total L: 45

REFERENCES:

1. James G. Bralla, “Design for Manufacturability Handbook”, McGraw Hill Professional, 1999.
2. Harry Peck, "Designing for Manufacture", Pitman Publications, 1983.
3. Matousek, "Engineering Design - A Systematic Approach", Blackie and Son Ltd., London, 1972.
4. Spotts M F, "Dimensioning and Tolerance for Quantity Production", Prentice Hall Inc., 1983.
5. Boothroyd G, Dewhurst P and Knight W, “Product Design for Manufacture and Assembly”, Marcell Dekker, 2015.
6. T. E. Graedel, Braden R. Allenby, “Design for environment” Prentice Hall, 1998.

21MC33 OPERATIONS MANAGEMENT

(vide ME INDUSTRIAL ENGINEERING - 21MN04 OPERATIONS MANAGEMENT)

21MC34 LEAN SIX SIGMA IN MANUFACTURING AND SERVICE

(vide ME INDUSTRIAL ENGINEERING -21MN21 LEAN SIX SIGMA IN MANUFACTURING AND SERVICE)

21MC35 COSTING AND ENGINEERING ECONOMICS

(vide ME Lean Manufacturing 21ML32 COSTING AND ENGINEERING ECONOMICS)

21MC36 GEOMETRIC MODELING

(vide ME ENGINEERING Design - 21MD24 GEOMETRIC MODELING)

21MC37 SUPPLY CHAIN MANAGEMENT

(vide ME INDUSTRIAL ENGINEERING - 21MN08 Supply Chain Management)

OPEN ELECTIVE THEORY COURSES (One to be opted)

21MD91 / 21MN91 / 21MC91 / 21SE91 BUSINESS ANALYTICS IN PRACTICE

3 0 0 3

INTRODUCTION TO BUSINESS ANALYTICS: Business analytics definition;Decision making; Framework for data-driven decision making; Challenges in data-driven; Business Analytics Process; Scope document; Project charter; Relationship of Business Analytics Process and organization; Competitive advantages of Business Analytics; Categorization of analytical methods and models; Data Mining; Data Mining Methodologies. (12)

OVERVIEW OF STATISTICAL TOOLS AND VISUALIZATION: Data types and scales, types of data measurement scales, population and sample, measures of central tendency, measures of variation, measures of shapes; Data visualization - exploring and discovering data using various types of graphs, tables and dashboards; Importance of Six Sigma, link DMAIC methodology to BA; Case Studies; Hands-on exercises; Use of software (R and Python). (13)

TRENDINESS AND REGRESSION ANALYSIS: Data modeling; Types - simple linear regression, least square method, multiple regression models; Model fitting and prediction with regression models; Case Studies; Hands-on exercises; Use of software (R and Python). (10)

FORECASTING TECHNIQUES: Types of forecasting; Forecasting techniques and forecasting accuracy; Types of Time Series models; Techniques to selecting appropriate forecasting models;Case Studies; Hands-on exercises; Use of software (R and Python). (10)

Total L: 45

REFERENCES:

1. U. Dinesh Kumar, "Business Analytics: The Science of Data - Driven Decision Making", Wiley India Pvt. Ltd., 2017.
2. Ohlmann, Jeffrey W, Anderson, David R, "Business Analytics" - 3rd Edition, Cengage, USA, 2019.
3. Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, "Business Analytics Principles, Concepts, and Applications: What, Why, and How", Pearson FT Press, 2014.
4. James Evans, "Business Analytics", Pearson Education, 2020.
5. R N Prasad, Seema Acharya., "Fundamentals of Business Analytics" - 2nd Edition, Wiley India, 2016.
6. Jeffrey D Camm, James J Cochran, Michael J Fry, Jeffrey W Ohlmann, David R Anderson, Dennis J Sweeney, Thomas A Wiiliams, "Essentials of Business Analytics", Cengage, USA, 2015.

21MD92 / 21MN92 / 21MC92 / 21SE92 LIFE CYCLE ASSESSMENT AND ECO-DESIGN

3 0 0 3

SUSTAINABILITY AND LCA: Introduction, magnitude of sustainability challenge, Energy, Material use, Environmental emissions, Economic and Social dimensions; LCA: Principles of LCA; Qualitative (approximate) LCA – Red Flag method, MET matrix; Quantitative LCA methods; Inventory analysis and allocation. (11)

LIFE CYCLE IMPACT ASSESSMENT AND METHODOLOGIES: Impact assessment systems – Components of impact assessment, Classification of impacts, Characterisation of equivalence factors, Environmental profiles; Normalisation – Normalised effects, Calculating an environmental profile; weighting- Comparing impact categories, Environmental index, Weighting principles, weighting triangle; Improvement Assessment-Uncertainties in impact assessment. (12)

STRATEGIES IN ECO DESIGN: Designing Eco-design – Product design reviews, Strategy wheel, Eco-design tools; New concept Development – Dematerialisation, Shared use of Products; Choosing low impact materials, reducing material flows, Design for production, distribution, “Green” use, Long life, End-of-life Design. (12)

LIFE CYCLE INTERPRETATION IN PRACTICE: Identification of significant issues, evaluation, reporting, critical review; LCA and life cycle management, life cycle thinking; Case studies (10)

Total L: 45

REFERENCES:

1. Giudice, F., La Rosa, G., Risitano, “A. Product Design for the Environment: A Life Cycle Approach” Ukraine, CRC Press, 2006.
2. Baumann H and Tillman A-M, “The Hitch Hiker’s Guide to LCA: An Orientation in Life Cycle Assessment Methodology and Application”, Studentlitteratur, 2004.
3. Klöpffer, Walter &Grahl, Birgit,“Life Cycle Assessment (LCA): A Guide to Best Practice”, Wiley, 2014.
4. European Platform on Life Cycle Assessment. ILCD Handbook. General guide for Life cycle assessment. Provisions and action steps. EU DG JRC IES, 2010.
5. Victor Papanek, “Design for the real world: Human ecology and social change”,Thames and Hudson, 1985.
6. Rosenbaum, Ralph K., and Olsen, Stig Irving, “Life Cycle Assessment: Theory and Practice”, Springer International

Publishing, 2017.

21MD93 / 21MN93 / 21MC93 / 21SE93 SYSTEMS ENGINEERING AND MANAGEMENT

3 0 0 3

FOUNDATIONS OF SYSTEMS ENGINEERING: Perspectives and the SE Landscape; Complex systems: elements and interfaces, hierarchy, building blocks, interactions, complexity in modern systems; Development process: system life cycle, evolutionary characteristics, testing; Work breakdown structure, organization of SE. (8)

SYSTEM DESIGN AND DEVELOPMENT: Conceptual design: planning and architecting, operational requirements, maintenance and support, technical performance measures, functional and trade-off analysis; Preliminary design: program documentation tree, functional flow block diagrams for subsystem, design definition, review, evaluation and feedback; Detailed design: Sequential versus concurrent approaches, integrating system elements and activities, parameter measurement and tracking, configuration control board; System test, evaluation and validation; Friedman-Sage framework;case studies:C-5A galaxy aircraft, Chattanooga smart bus, baggage handling, water management system; solving DMSMS issue, lessons learnt. (12)

MODELS AND COSTS IN DECISION MAKING: Formulation of models, Classification, decision evaluation theory, direct ranking, systematic elimination, graphical additive method, decision making under risk and uncertainty, Hurwicz criterion; Investment costs, optimizing life-cycle costs, procurement and inventory operations, estimation of equipment life; Multi-criteria optimization: super structure design and procurement source preference, mathematical and graphical problem solving. (15)

CONTROL METHODS AND DESIGN FOR X: Control methods: applications of control charts for variables:delta, moving range and Shewhart charts;control charts for attributes: p, np, c and u; quality loss function; DFX for system excellence:maintainability, producibility, disposability, and sustainability. (10)

Total L: 45

REFERENCES:

1. Benjamin S. Blanchard and Wolter J. Fabrycky, “Systems Engineering and Analysis”, Pearson Education, 5th Edition, 2014.
2. Hiroki Sayama, “Introduction to the Modeling and Analysis of Complex Systems”, Open SUNY Textbooks, 1st Edition, 2015
3. ReinhardHaberfellner, Olivier de Weck, Ernst Fricke and Siegfried Voessner “Systems Engineering: Fundamentals and Applications”, Springer Nature, 1st Edition, 2019.
4. Joseph Eli Kasser, “Systems Engineering”, CRC Press, 1st Edition, 2019.
5. Howard Eisner, “Systems Engineering: Fifty Lessons Learned”, CRC Press, 1st Edition, 2020.
6. Alexander Kossiakoff, Steven M. Biemer, Samuel J. Seymour and David A. Flanigan, “Systems Engineering Principles and Practice”, Wiley, 3rdEdition, 2020.