

## 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; First Edition, 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, tachogenerator; 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 Hestand, 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 PLAN AND 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 Williams, "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, 1<sup>st</sup> Edition, 2015
3. Reinhard Haberfellner, Olivier de Weck, Ernst Fricke and Siegfried Voessner “Systems Engineering: Fundamentals and Applications”, Springer Nature, 1<sup>st</sup> Edition, 2019.
4. Joseph Eli Kasser, “Systems Engineering”, CRC Press, 1<sup>st</sup> Edition, 2019.
5. Howard Eisner, “Systems Engineering: Fifty Lessons Learned”, CRC Press, 1<sup>st</sup> Edition, 2020.
6. Alexander Kossiakoff, Steven M. Biemer, Samuel J. Seymour and David A. Flanigan, “Systems Engineering Principles and Practice”, Wiley, 3<sup>rd</sup> Edition, 2020.