SEMESTER I

21MC01 STATISTICAL INFERENCE AND MULTIVARIATE ANALYSIS
Vide Industrial Engineering 21MN01

21MC02 INTEGRATED PRODUCT DEVELOPMENT

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-yake, 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:

21MC03 BUSINESS OPERATIONS INTEGRATION

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:
21MC04 INDUSTRIAL AUTOMATION AND CONTROL

SENSEY 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, magnetostatic 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:

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)


(11)


(11)

Total L: 45

REFERENCES:

21MC06 Research Methodology and IPR
vide Automotive Engineering 21AE06

2 0 0 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
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.

REFERENCES:
1. Sensor Interface and Robotics Laboratory Manual prepared by Department of Mechanical Engineering, PSG College of Technology.

21MC52 MANUFACTURING SIMULATION AND IoT LABORATORY

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
2. Logistics simulation and inventory analysis.
5. Sensor data analytics of IoT devices.

CASE STUDY
Visualization of bottlenecks in a manufacturing plant and machine monitoring using IoT.

REFERENCES:
1. Manufacturing Simulation and IoT Laboratory Manual, Department of Mechanical Engineering, PSG College of Technology.

SEMESTER II

21MC07 INDUSTRIAL ROBOTICS

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

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.

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.

REFERENCES:

21MC08 COMPUTER CONTROLLED MACHINE TOOLS

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.

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.

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.

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.

REFERENCES:

21MC82 AUDIT COURSE II
vide Automotive Engineering 21AE82

21MC61 CAD / CAM / CAE LABORATORY

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.

**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

**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.
4. Automated inspection of components using image processing.

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

**REFERENCES:**
1. Automated Manufacturing Systems Laboratory Manual, Department of Mechanical Engineering, PSG college of Technology.

**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)

REFERENCES:

21MC22 ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

3 0 0 3


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)

REFERENCES:

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:
3. Timothy Jung and M. Claudia Tom Dieck, "Augmented Reality and Virtual Reality: Empowering Human, Place and Business", Springer, 2018

21MC24 AUTOMATIC CONTROL SYSTEMS

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.

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.

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.

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.

Total L: 45

REFERENCES:

21MC25 INDUSTRIAL INTERNET OF THINGS

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.

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.

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.

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.

Total L: 45

REFERENCES:
1. Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress; First Edition, 2019
21MC26 ADDITIVE MANUFACTURING

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)

REFERENCES:

21MC27 ADVANCED MANUFACTURING PROCESSES

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)


REFERENCES:
21MC28 METROLOGY AND AUTOMATED INSPECTION

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)

REFERENCES:

TOTAL L: 45

21MC29 SHEET METAL CUTTING AND BENDING TECHNOLOGIES

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, oxygen-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)

REFERENCES:

TOTAL L: 45

21MC30 MANUFACTURING SYSTEMS DESIGN AND ANALYSIS

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)

ANALYSIS 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, Carousel storage systems; Introduction to material handling and storage software. (11)

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

REFERENCES:

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)

REFERENCES:

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)

REFERENCES:

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

**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.

**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).

**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).

**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).

**REFERENCES:**

Total L: 45

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

**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.

**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.

**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.

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

Total L: 45

**REFERENCES:**
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: