Duration of the Course: 2Years

Syllabus

FIRST SEMESTER						SECOND SEMESTER					
Sub. Code	**Subject Name**	**L**	**T**	**P**	**C**	**Sub. Code**	**Subject Name**	**L**	**T**	**P**	**C**
MIE ****	CAD/CAM for Additive Manufacturing	3	1	0	4	MIE ****	Virtual Manufacturing and Rapid Prototyping	3	1	0	4
MIE ****	Advanced Manufacturing Process	3	1	0	4	MIE ****	Finite Element Methods in Digital Manufacturing	3	1	0	4
MIE ****	Digital Product Design and Manufacturing	3	0	0	4	MIE ****	Program Elective-I	3	1	0	4
MIE ****	Digital Twin in Manufacturing	3	0	0	4	MIE ****	Program Elective-II	3	1	0	4
MIE ****	Industrial IoT and Haptics	3	0	0	4	MIE ****	Program Elective-III	3	0	0	3
MIE ****	Industrial IoT Lab	0	0	3	1	MIE ****	Open Elective - I	3	0	0	3
MIE ****	Advanced Material Testing Lab	0	0	3	1	HUM ****	*Research Methodology and Technical Communication	1	0	3	2
MIE ****	Manufacturing Control and Automation Lab	0	0	3	1	MIE ****	Additive Manufacturing Virtual Lab	0	0	3	1
HUM ****	*Research Methodology and Technical Communication					MIE ****	Mechanism and Robotics Virtual Lab	0	0	3	1
						MIE ****	Flexible Manufacturing Systems Virtual Lab	0	0	3	1
					23						**27**
Total Contact Hours (L+ T+P)		**23**				**Total Contact Hours (L+ T+P)**		**27**			

THIRD AND FOURTH SEMISTER					
MIE ****	**Project work and Industrial Training**	**0**	**0**	**0**	**25**

Programme Electives

PROGRAM ELECTIVES		OPEN ELECTIVES	
COURSE CODE	**COURSE TITLE**	**COURSE CODE**	**COURSE TITLE**
	PROGRAM ELECTIVE I	MIE ****	Big Data Analytics for Manufacturing
MIE ****	Micro and Nano Manufacturing	MIE ****	Virtual Reality
MIE ****	Advanced Manufacturing Tooling	MIE ****	Rapid Tooling and Industrial Application
MIE ****	Precision Engineering	MIE ****	Cyber Security for Manufacturing
MIE ****	Surface Engineering	MIE ****	Quality Control and Reliability
MIE ****	Advanced Metal Casting and Joining Technology	MIE ****	Renewable Energy Technology
MIE ****	Design for Manufacturing		
	PROGRAM ELECTIVE II		
MIE ****	Applied Artificial Intelligence for Manufacturing		
MIE ****	Sustainable Manufacturing		
MIE ****	Manufacturing of Non-Metallic Products		
MIE ****	Manufacturing Control and Automation		
MIE ****	Lean Manufacturing		
MIE ****	Mechanism and Robotics		
	PROGRAM ELECTIVE III		
MIE ****	Smart Materials and Sensors		
MIE ****	Computer Integrated Manufacturing Systems		
MIE ****	Supply Chain Management		
MIE ****	Mechanics of Bulk Metal Forming		
MIE ****	Flexible Manufacturing System		
MIE ****	Advanced Materials Processing and Characterization		

CAD/CAM FOR ADDITIVE MANUFACTURING [3 1 0 4] [4 Credits]

Introduction to Design for Additive Manufacturing (DfAM): Introduction to geometric modelling, Modelling of Synthetic curves like Hermite, Bezier and B-spline, Parametric Representation of freeform surfaces, Design freedom with AM, Need for Design for Additive Manufacturing (DfAM), CAD tools vs. DfAM tools, Requirements of DfAM methods, General Guidelines for DfAM, The Economics of Additive Manufacturing, Design to Minimize Print Time, Design to Minimize Post-processing. **Design Guidelines for Part Consolidation:** Design for Function, Material Considerations, Number of Fasteners, Knowledge of Conventional DFM/DFA, Assembly Considerations, Moving Parts, Part redesign, Opportunities for part consolidation, challenges with part consolidation. **Design for Improved Functionality:** Multi scale design for Additive manufacturing, Mass customization, Biomimetics, Generative design, Design of multimaterials and functionally graded materials. **Design for Minimal Material Usage:** Topology Optimization, Modelling of Design space, defining design and manufacturing constraints, performing analysis for weight reduction, maximize stiffness, minimize displacement, Postprocessing and Interpreting Results, Applications of TO, TO tools, Design of cellular and lattice structures, Design of support structures. Computational Tools for Design Analysis: Considerations for Analysis of AM Parts, Material Data, Surface Finish, Geometry, Simplifying Geometry, MeshBased Versus Parametric Models, Build Process. **Simulation:** Model Slicing, Contour Data Organization, Layer-by-Layer Simulation, Hatching Strategies,Scan Pattern Simulation and Tool Path Generation. **Design for Polymer AM:** Anisotropy, Wall Thicknesses, Overhangs, Support Material, Accuracy,Tolerances, Layer Thickness, Resolution, Print Orientation, Warpage, over sintering, Hollowing Parts, Horizontal Bridges, Connections, Fill Style, holes, fillets, ribs, font sizes and small details.**Design for Metal AM:** Powder Morphology, Powder Size Distribution, Material Characteristics,Designing to Minimize Stress concentrations, Residual Stress, Overhangs, shrinkage, warpage and Support Material, Design Guidelines for Wall Thickness, Clearance Between Moving Parts, Vertical Slots, Circular Holes, fillets, channels, vertical Bosses, circular pins, External Screw Threads and part positioning. **Other AM Considerations:** Designer Machine Operator Cooperation, Health and Safety, Material Exposure, Gas Monitoring, Gas Exhaust, Material Handling, Risk of Explosion, AM Part Standardization and Certification.

References:

1. A Practical Guide to Design for Additive Manufacturing, Diegel, Olaf, Axel Nordin, and Damien Motte,Springer, 2020.
2. The 3D Printing Handbook: Technologies, Design and Applications, Redwood, Ben, Filemon Schoffer, and Brian Garret, 3D Hubs, 2017.
3. Design for Advanced Manufacturing: Technologies and Process, Laroux K, Gillespie, McGrawHill,2017.
4. Additive Manufacturing Technologies, Gibson, Ian, David W. Rosen, Brent Stucker, and Mahyar Khorasani, Springer, 2021.

5. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma,Springer, 2004.

ADVANCED MANUFACTURING PROCESSES [3 1 0 4] [4 Credits]

Non-traditional manufacturing processes: AJM, WJM, AWJM and USM working principle, Equipment, Process parameters, Electrical EDM & WEDM - Working principle, Equipment, Process parameters, CHM and ECM, working principle, Equipment, Process parameters, LBM, PAM, EBM Working principle, Equipment, Process parameters, **Advanced casting processes:** Metal mould casting, Continuous casting, squeeze casting, Vacuum mould casting, Evaporative pattern casting, Ceramic shell casting. **Advanced welding processes:** Electron beam welding (EBW), Laser beam welding (LBW), Utra-sonic welding (USW), **High energy rate forming (HERF) processes:** Electromagnetic forming, Explosive forming, Electro-hydraulic forming, Stretch forming, and Contour roll forming, Rapid prototyping and rapid manufacturing.

References:

1. Bhattacharya, New technology, Institution of Engineers, India.
2. HMT, Production technology, Tata McGraw Hill.
3. PS Pandy& H.S Shan, Modern Machining Process, Tata McGraw Hill.
4. ASM, Metals hand book, Vol-3.
5. F.M Wilson, High velocity forming of metals, ASTMW Pretence Hall.

DIGITAL PRODUCT DESIGN AND MANUFACTURING [3 1 0 4] [4 Credits]

Concept of Product Design: Definition of engineering design, design constraints, different phases in design- conceptual design, embodiment design, detail design, planning for manufacture, planning for distribution, planning for use, Human factors design- ergonomics, anthropometry, comfort criteria, concepts of size, texture and colour, Introduction to product design, product design practices in industry. **Tools for product design**: drafting-modelling software CAE/CAD, computer aided styling, production process- CAM interface, product development- time and costs. Description of planning for product distribution, Economic factors affecting design. **Digital tool enabled design-I:** Evolution of digital tools for product design and manufacturing, 2D/3D models to digital mock-up and virtual prototyping (VP). Virtual reality (VR), augmented reality (AR) and Mixed reality, Implementation in product design and manufacturing. Interaction technology, Visualisation technology, Visual display-types- head mounted, organic LEDs, large volume displays, wall type, equipments, characteristics. **Digital tool enabled designII:** AR-, tangible, collaborative; examples; AR tracking technology and devices; interaction techniques, haptic technology, olfactory technology. Product digitalization, analysis and simulation. Virtual humans (VH)- for clothing, for ergonomics analysis, biomechanical models. **Digital manufacturing:** 3D printing- additive manufacturing technology- Classification of additive manufacturing technologies: vat- photo polymerisation, powder bed fusion, material jetting, sheet lamination, material extrusion and direct energy deposition, infill lattice structures.

References:

1. George Dieter and Linda C. Schmidt, Engineering Design, 4th Edition, Published by McGraw-Hill.

2. Monica Bordegoni and Caterina Rizzi, “Innovation In Product Design From CAD To Virtual Prototyping”, Springer.
3. Karl T Ulrich and Steven D Eppinger, “Product Design & Development.” Tata Mc- Graw Hill, 2003.
4. Ian Gibson, David Rosen and Brent Stucker, “Additive Manufacturing Technologies-3D Printing, Rapid Prototyping, and Direct Digital Manufacturing.” Springer.
5. Fei Tao, Meng Zhang and A. Y. C. Nee, “Digital Twin Driven Smart Manufacturing”, Academic Press, Elsevier.
6. D. T. Pham, S.S. Dimov, Rapid Manufacturing-The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer – Verlag, London, 2001.
7. Kevin Otto & Kristin Wood Product Design: “Techniques in Reverse Engineering and New Product Development.”, Pearson Education New Delhi, 2000.
8. N J M Roozenberg , J Ekels , N F M Roozenberg “ Product Design Fundamentals and Methods’’. John Wiley & Sons.
9. AK Chitale & RC Gupta, “Product Design and Manufacturing”, PHI, 2000.

DIGITAL TWIN IN MANUFACTURING[3 1 0 4] [4 Credits]

Introduction to Digital Twins and Architecture: Overview of Digital Twins, Definition and history, Importance in manufacturing, Industry 4.0 and the role of digital twins **Data acquisition in digital Twin:** The Need for Electronics in Manufacturing, signal processing and importance of digital twin, Image Processing for Digital Twin: Image enhancement, segmentation and introduction to image processing in manufacturing. **Data communication in digital twin**: Overview, IoT and Network IoT Framework, Introduction to the Edge, Fog, and Cloud Computing, The Necessity of Cloud and Edge Computing in Industry, Real-Life Example in Manufacturing **Data-driven modelling and machine learning for digital twins:** Introduction to Artificial Intelligence, Requirement of Artificial Intelligence in a Digital Twin, Mathematical modelling, Physical and process modelling, Predictive maintenance, Real-time analytics **Digital Twin Application:** Digital Twins for Design and Manufacturing, Digital Twins for Service, Challenges and Intelligence, Real-Life Examples in Manufacturing.

References:

1. “Building Industrial Digital Twins Design, Develop, and Deploy Digital Twin Solutions for Realworld Industries Using Azure Digital Twins” Shyam Varan Nath, Pieter van Schalkwyk, Dan Isaacs Packet Publishing
2. “Digital twin driven smart design “ Tao F, Liu A, Hu T, Nee AY. Academic Press; 2020.
3. “Digital Twin Technology Fundamentals and Applications”, Manisha Vohra Wiley 2022
4. “Digital Twin – Fundamental, Concepts to Applications in Advanced Manufacturing” Surjya Kanta Pal, Debasish Mishra , Arpan Pal Samik Dutta, Debashish Chakravarty , Srikanta Pal Springer

IIOT AND HAPTICS[3 1 0 4] [4 Credits]

Introduction to IIoT: Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals-Devices and gateways, Data management, Business processes in IoT, Everything as a Service

(XaaS), Role of Cloud in IoT, Security aspects in IoT. **Elements of IIoT:** Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication ProtocolsMQTT, ZigBee, Bluetooth, CoAP, UDP, TCP. **IIoT & Cloud Application Development:** Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Cloud service and platforms: Commercial clouds (such as Amazon elastic compute cloud, Google Compute engine, Windows Azure), Storage services, database services, application services, content delivery services, analytics services. **Case Studies:** IIoT & Cloud based case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation. **Haptic Technology:** Introduction to haptic systems and their applications, Generating haptic-feedback with a manipulator, Generating haptic-feedback with a manipulator, Introduction to haptic rendering, Real-time programming for generating force-feedback, Introduction to force-feedback telemanipulation, Haptic rendering of rigid bodies (collision detection), Haptic rendering of rigid bodies (force shading, friction rendering and texture rendering), Stability of haptic systems.

References:

1. Vijay Madisetti, Arshdeep Bahga, A Hands on Approach", Internet of Things, University Press, 2020.
2. Troy McDaniel and Sethuraman Panchanathan, Haptic Interfaces for Accessibility, Health, and Enhanced Quality of Life, Springer, 2020.
3. The Internet of Things: Enabling Technologies, Platforms, and Use Cases", Pethuru Raj and Anupama C. Raman, CRC Press, 2012
4. Designing the Internet of Things", Adrian McEwen, Wiley, 2015

VIRTUAL MANUFACTURING AND RAPID PROTOTYPING [3 1 0 4] [4 Credits]

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. **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. **Modelling and Simulation:** Geometric modelling: virtual object shapes, visual appearance, object hierarchies, model management, LOD; **Simulation:** physical modelling, bounding volumes, handling collision detection; Response: transformation, force computation, surface deformation, haptic texturing. **Validation and Analysis:** Design validation, verification by simulation, analysis of manufacturing processes, material handling and storage system, process layout, plant maintenance. **Rapid Prototyping**: Classification and Definition, Strategic Aspects for the Use of Prototypes, Applications of Rapid Prototyping in Industrial Product Development. Rapid Tooling: Classification and Definition of Terms, Properties of Additive Manufactured Tools, Indirect Rapid Tooling Processes: Molding Processes and Followup Processes, Indirect Methods for the Manufacture of Tools for Plastic Components, Indirect Methods for the Manufacture of Metal Components. **Rapid Tooling:** Tools based on Plastic Rapid Prototyping Models and Methods.

Metal Tool Based on Multilevel AM Processes,Direct Tooling, Tools based on Metal RP processes. **Rapid manufacturing:** Feasibility, Cost estimation, Breakeven analysis, Sustainability Aspects.

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.

FINITE ELEMENT METHODS IN DIGITAL MANUFACTURING [3 1 0 4] [4 Credits]

Introduction: General procedure of FEM. **Formulation Methods - Direct Method:** Spring and truss elements,arbitrarily oriented elements, transformation matrix,plane truss. **Energy Method:** Principle of total minimum potential energy, Formulation of plane stress/strain elements. **Galerkin's Weighted Residual Method:** Beam theory, formulation of beam element, arbitrarily oriented beam elements, plane frame. **Isoparametric Elements:** Formulation of truss, plane and solid elements. **Introduction to Analysis Types:** Modal or frequency analysis, thermal analysis, thermosstructural analysis, axi-symmetric analysis, fluid flow analysis. **Software Practices:** Finite element analysis on a software system for finding solution of FEM based problems related to stress-strain analysis. Application of FEM in manufacturing engineering

References:

1. Daryl L Logan, A First Course in Finite Element Method, Thomson Asia Pvt. Ltd,Bangalore, 2002.
2. Bathe K J, Finite Element Procedures, Prentice Hall of India New Delhi, 2003.
3. Martin H.C. and Carey G.F., Introduction to Finite Element Analysis, Tata McGraw Hill,New Delhi, 1975.
4. Segerlind L J., Applied Finite Element Analysis, John Wiley, New York, 1984.
5. Cook Robert D, Concepts and Applications of Finite Element Analysis, John Wiley and Sons New York, 2000

RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION [1 0 3 2] [2 Credits]

Research Methodology: Basic concepts: Types of research, Significance of research, Research framework. Sources of data, Methods of data collection. **Research formulation:** Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. **Research hypothesis:** Criterion for hypothesis construction, Nature of hypothesis, Characteristics and Types of hypothesis, Elements of research design, Introduction to various sampling methods Sources of data, Collection of data, Research reports, references styles, Effective Presentation techniques, Research Ethics.

References:

1. Sekaran, U., & Bougie, R. (2016). Research methods for business: A skill building approach. John Wiley &Sons.
2. Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2013). Business research methods. Cengage Learning.
3. Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage Publications.
4. Donald R Cooper & Pamela S Schindler, Business Research Methods, McGraw Hill International, 2018.

MICRO AND NANO MANUFACTURING[3 1 0 4] [4 Credits]

Introduction: Importance of Nanotechnology, Emergence of Nanotechnology, Bottom-up and Top-down approaches, challenges in Nanotechnology, Scaling Laws in Mechanics, fluids, thermodynamics, Electromagnetism, tribology and Examples. **Nano-materials Synthesis and Processing:** Methods for creating Nanostructures; Processes for producing ultrafine powders-Mechanical grinding; Wet Chemical Synthesis of nano-materials- sol-gel process, Liquid solid reactions; Gas Phase synthesis of nano-materials. **Structural Characterization:** X-ray diffraction, Optical Microscope and their description, Scanning Electron Microscopy (SEM), TEM and EDAX analysis, Scanning Tunneling Microscopy (STM), Atomic force Microscopy (AFM). **Micro fabrication Techniques:** Lithography – LIGA, Thin Film Deposition and Doping, Etching and Substrate Removal, Substrate Bonding, MEMS Fabrication Techniques, Bulk Micromachining, Surface Micromachining, High- Aspect-Ratio Micromachining **Nanofabrication Techniques:** Laser based nano manufacturing, E-Beam and Nano-Imprint Fabrication, Epitaxy and Strain Engineering, Scanned Probe Techniques, Self-Assembly and Template Manufacturing. **MEMS devices and applications:** Pressure sensor, inertial sensor, Optical MEMS and RF-MEMS, Microactuators for dual-stage servo systems.

References:

1. MEMS and Microsystems: Design and Manufacture, Tai-Ran Hsu, McGraw- Hill, 2008 2. Fundamentals of Microfabrication: The Science of Miniaturization, Marc Madou, CRC Press, 2002, Second Edition.
3. Microfabrication and Nano manufacturing, Mark James Jackson, CRC Press, 2005.
4. Introduction to Nanoscience and Nanotechnology, Gabor L. Hornyak, H.F Tibbals, Joydeep Dutta & John J Moore, CRC Press, 2009.
5. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, Ray F. Egerton, Springer, 2005.
6. Thermal Analysis of Materials, Robert F Speyer, Marcel Dekker Inc. New York, 1994.
7. Elements of X-Ray Diffraction, B.D. Cullity, Prentice Hall, 2002, 3rd edition.

ADVANCED MANUFACTURING TOOLING [3 1 0 4] [4 Credits]

Tool Design: Drafting and Design Techniques in Tooling, Modern Tool making practices, Tooling materials and heat treatment. **Design of Press Tools Dies Types of Dies**: Method of Die operation,Clearance and cutting force calculations,Blanking and Piercing die design ,Pilots, Strippers and pressure pads,Presswork materials, Strip layout , Short-run tooling for Piercing. **Design of Forming Dies**: Bending dies ,Forging dies , Extrusion dies , Drawing dies , Design and drafting,Casting Dies and Welding dies, Design. **Design of Jigs**: Types of drill jigs , design of drill jigs , Drill bushings, Types, methods of construction, Simple designs of Plate, Channel, Boxes, Post, Angle plate, Turnovers and Pot Jigs. **Design of Fixtures:** Design principles, Types of fixtures, Fixtures for machine tools, Lathe, Milling, Boring, Broaching and grinding, Computer aided conceptual fixture design, Assembly fixtures, Modular fixtures. **Design of Cutting tools**: Mechanics of Metal cutting ,Oblique and orthogonal cutting, Chip formation and shear angle , Single-point cutting tools ,Milling cutters ,Hole making cutting tools, Broaching Tools, Design of Form relieved and profile relieved cutters,Design of gear and thread milling cutters. **Tool Design for CNC Machine tools:** Introduction ,Tooling requirements for Numerical control systems,Fixture design for CNC machine tools,Sub plate and tombstone fixtures,Universal fixtures, Cutting tools,Tool holding methods,Automatic tool changers and tool positioners ,Tool presetting.

References:

1. Donaldson C., Lecain G.H. and Goold V.C., (2012), Tool Design, 4th edition, Tata McGraw-Hill Publishing Company Ltd., New Delhi
2. E.G.Hoffman, (2004), Jig and Fixture Design, Thomson Asia Pte. Ltd, Singapore Prakash Hiralal Joshi, (2000), Tooling data, Wheeler Publishing
3. Venkataraman K., (2005), Design of Jigs, Fixtures and Presstools, TMH
4. Andrew Y C Nee, A. Senthil Kumar and Z J Tao,(2004), An Advanced Treatise on Fixture Design and Planning, World Scientific Publishing Co Pte Ltd.

PRECISION ENGINEERING [3 1 0 4] [4 Credits]

Introduction to precision engineering: Accuracy and precision concepts, need for precision, tolerance systems. Materials for precision engineering: Diamond tools, CBN, ceramics, ultra-high precision materials. **Precision machining processes:** Ultra-precision turning, diamond machining, micro-grinding. **Precision measurement:** Coordinate measuring machines (CMM), laser interferometry, optical measurement. **Environmental control:** Temperature control, vibration isolation, clean room requirements. **Machine tool design:** Static and dynamic stiffness, thermal stability, spindle design. Error analysis: Geometric errors, thermal errors, error compensation techniques. **Micro and nano manufacturing:** Lithography, MEMS fabrication, nano-finishing processes. **Surface metrology:** Surface texture measurement, form measurement, roundness measurement. Quality assurance: Calibration procedures, measurement uncertainty, traceability.

References:

1. Murty, R.L., "Precision Engineering in Manufacturing", New Age International
2. Venkatesh, V.C., Sudin, I., "Precision Engineering", Tata McGraw Hill
3. Zhang, L., "Precision Machining of Advanced Materials", Trans Tech Publications
4. Jiang, X.J., Scott, P.J., "Advanced Metrology: Freeform Surfaces", Academic Press

SURFACE ENGINEERING [3 1 0 4] [4 Credits]

Introduction to surface engineering: Surface properties, failure modes, surface degradation mechanisms. **Wear mechanisms:** Adhesive wear, abrasive wear, fatigue wear, corrosive wear. **Surface modification techniques:** Heat treatment, mechanical treatment, chemical treatment.

Coating technologies: Thermal spraying, CVD, PVD, electroplating. Hard facing processes: Arc welding processes, thermal spray processes, fusion alloys. **Surface alloying:** Laser alloying, ion implantation, diffusion processes. Tribology: Friction mechanisms, lubrication, surface interactions. **Characterization methods:** Surface roughness measurement, coating thickness, adhesion testing. Applications: Automotive components, tooling applications, biomedical implants. **Quality control:** Testing methods, failure analysis, performance evaluation.

References:

1. Dwivedi, D.K., "Surface Engineering: Enhancing Life of Tribological Components", Springer
2. Davis, J.R., "Surface Engineering for Corrosion and Wear Resistance", ASM International
3. Budinski, K.G., "Surface Engineering for Wear Resistance", Prentice Hall
4. ASM Handbook, "Surface Engineering", Vol. 5, ASM International

METAL CASTING AND JOINING TECHNOLOGY [3 1 0 4] [4 Credits]

Casting: Patterns, pattern allowances, mould and core making, melting practice and furnaces, cooling and solidification, Elements and design of gating system and risers, application of chills. Different moulding and casting processes, Casting defects, Fettling and testing of casting.

Welding and Allied Processes: Classification, structure and characteristics of welding arc, arc welding power sources, duty cycle, metal transfer, Selection of Welding process. Different welding processes:Shielded Metal Arc Welding (SMAW), Submerged Arc Welding (SAW), Gas Tungsten Arc Welding (GTAW/TIG), Gas Metal Arc Welding (GMAW),Electro-slag and Electro-gas welding, Resistance welding, Solid-state welding processes, Diffusion welding, Ultrasonic welding, Electron beam welding, Laser welding, Plasma arc welding, Thermit welding, Weld defects, Brazing and Soldering. **Welding Metallurgy:** Heat flow in welding, Metallurgical transformation in and around weldment, Implication of cooling rates, Heat affected zone (HAZ), Weldability of steels, Design of weldments, Destructive and Non-destructive tests of welding joints.

References:

1. H.S. Bawa, Manufacturing Technology-I, TMH Publications, New Delhi, 2007.
2. S.V. Nadkarni, Modern Arc Welding Technology, Oxford and IBH Publishing Co.Pvt. Ltd., 2010.
3. SeropeKalpakjian and Steven R. Schmid, Manufacturing Processes for Engineering Materials, 4th edition, Pearson Education, 2007.
4. P. L. Jain, Principles of Foundry Technology,5th edition, 2009.

SUSTAINABLE MANUFACTURING [3 1 0 4] [4 Credits]

Introduction to sustainability: Triple bottom line, environmental impact assessment. **Life Cycle Assessment (LCA):** LCA methodology, impact categories, interpretation. Sustainable design: Design for environment, eco-design, circular economy principles. **Resource efficiency:** Material efficiency, energy efficiency, water conservation. Waste management: Waste minimization, recycling, reuse strategies. **Cleaner production:** Pollution prevention, source reduction, process modification. **Renewable energy in manufacturing:** Solar, wind, biomass applications in industry. **Green manufacturing processes:** Green machining, bio-based materials, additive manufacturing. **Supply chain sustainability:** Sustainable sourcing, transportation, logistics.

Performance measurement: Sustainability indicators, reporting frameworks. Regulatory framework: Environmental regulations, standards, compliance.

References:

1. Gutowski, T., "Manufacturing and the Environment", MIT Press
2. Allwood, J.M., "Sustainable Manufacturing", Springer
3. Dornfeld, D., "Green Manufacturing: Fundamentals and Applications", Springer 4. Jawahir, I.S., "Sustainable Manufacturing", ASME Press

DESIGN FOR MANUFACTURING [3 1 0 4] [4 Credits]

DFM principles: Design for manufacturability guidelines, concurrent engineering. **Material selection:** Material properties, manufacturing constraints, cost considerations. **Process selection:** Manufacturing process capabilities, process selection charts. **Design for machining:** Machining guidelines, fixture design, tool accessibility. **Design for casting:** Casting design rules, gating systems, solidification considerations. **Design for forming:** Sheet metal forming, bulk forming, design guidelines. **Design for assembly:** Assembly methods, fastening techniques, automation considerations. Design for joining: Welding design, adhesive bonding, mechanical fastening.
Tolerancing: Geometric dimensioning and tolerancing, tolerance analysis. **Cost estimation:** Manufacturing cost models, design cost analysis. **Case studies:** Automotive components, consumer products, aerospace applications.

References:

1. Boothroyd, G., Dewhurst, P., Knight, W., "Product Design for Manufacture and Assembly", CRC Press
2. Bralla, J.G., "Design for Manufacturability Handbook", McGraw Hill
3. Otto, K., Wood, K., "Product Design", Pearson Education
4. Poli, C., "Design for Manufacturing: A Structured Approach", Butterworth-Heinemann

APPLIED ARTIFICIAL INTELLIGENCE FOR MANUFACTURING [3 1 0 4] [4 Credits]

Overview of AI in manufacturing: Application of Machine Learning to Industrial Planning and Decision Making Special Purpose Resource Design in Planning to Make More Efficient Plans; Geometric Reasoning Using a Feature Algebra, Backward Assembly Planning Symmetry Groups in Solid Model-Based Assembly Planning**. AI at the workstation level:** An Expert System Approach for Economic Evaluation of Machining Operation Planning, Interactive Problem Solving for Production Planning, An Abstraction-Based Search and Learning Approach for Effective Scheduling, **ADDYMS:** Architecture for Distributed Dynamic Manufacturing Scheduling, An Architecture for Real-Time Distributed Scheduling, Exploiting Local Flexibility During Execution of Pre-computed Schedules An Architecture for Integrating Enterprise Automation; An Intelligent Agent Framework for Enterprise Integration; **Teamwork Among Intelligent Agents:** Framework and Case Study in Robotic Service Symbolic Representation and Planning for Robot Control Systems in Manufacturing; Integrated Software System for Intelligent Manufacturing; **Enterprise Management Network Architecture:** A Tool for Manufacturing Enterprise Integration; Design and Manufacturing: Integration through Quality Introduction to Digital Twin and Cyber-Physical Manufacturing Systems.

References:

1. A. Fazel Famili (Editor), Dana S. Nau (Editor), Steven H. Kim (Editor); Artificial Intelligence Applications in Manufacturing, AAAI Press.
2. Ellen Friedman, Ted Dunning, AI and Analytics in Production; O'Reilly Media, Inc., 2018 (ISBN: 9781492044116)
3. Çağlayan Arkan, The Future Computed: AI and Manufacturing; Global Lead, Manufacturing and Resources Industry, Microsoft, 2019.
4. A. Fazel Famili (Editor), Dana S. Nau (Editor), Steven H. Kim (Editor); Artificial Intelligence Applications in Manufacturing, AAAI Press.
5. Ellen Friedman, Ted Dunning, AI and Analytics in Production; O'Reilly Media, Inc., 2018 (ISBN: 9781492044116)
6. Çağlayan Arkan, The Future Computed: AI and Manufacturing; Global Lead, Manufacturing and Resources Industry, Microsoft, 2019.

MANUFACTURING OF NONMETALLIC PRODUCTS [3 1 0 4] [4 Credits]

Introduction to Non-Metallic Materials: Classification, **Polymers:** Classification of Polymers, Machining of Polymers, Rubbers: Properties and Applications of Rubber, Rubber Forming Processes, **Glass:** Types of Glasses, **Processing and Manufacturing Techniques of Glass Vessels: Ceramics:** Processing of Ceramics, **Casting:** Slip Casting, Tap Casting, **Plastic Forming:** Mounted Abrasive Machining, Free Abrasive Machining, Impact Abrasive Machining, **Composites:** Classification and Properties of Composites, Properties and Secondary Processing Techniques, **Rapid Prototyping (RP) in Manufacturing of Non- Metallic Products;** Different RP Processes and Equipment used in Manufacturing of Non-Metallic Components.

References:

1. Polymer Science and Technology-Plastics,Rubber, Blends and Composites by Ghosh,TMH.
2. Rubber Processing Technology, Materials and Principles by J.L. White, Hanser Publishers.
3. Glass Engineering Handbook by E. B. Shand, McGraw-Hill.
4. Introduction to Ceramics by Kingery Bowen and Uhlmann, John Wiley & Sons publishers.
5. Handbook of Composites by George Lubin, Springer.

MANUFACTURING CONTROL AND AUTOMATION [3 1 0 4] [4 Credits]

Overview of Manufacturing and Automation: Production systems, Automation in production systems, Automation principles and strategies, Reasons for Automation, Manufacturing operations, Functions in Manufacturing, Information processing in Manufacturing plant layout, production facilities. Basic elements of an automated system, levels of automation; Hardware components for automation and process control, programmable logic controllers and personal computers. Automation for machining operations. Assembly Systems and Line Balancing-Assembly Process-Assembly lines-manual single stations assembly, Manual assembly line, automated assembly System-Line balancing. Automated Assembly Systems – Design for automated Assembly-Types of automated assembly Systems-Parts feeding devices.**Automated**

Material Handling and storage system: Material Handling and Identification Technologies: Material handling, equipment, Analysis. Storage systems, performance and location strategies, Automated storage systems, AS/RS, types. Functions, material handling equipment- Conveyors, AGVS, Industrial Robots-Anatomy, Robot configurations, work volume-AS/RS. Introduction to oil hydraulics and pneumatics, Advantages and limitations, Introduction to Hydraulic systems, Hydraulic actuators and accessories, calculation of force, speed, rotary actuators, accumulator, Hydraulic valves,Construction and working of various types of Direction control valves, Hydraulic circuits. Components of the pneumatic system: Air generation and distribution, Constructional details and working of filter, lubricator, pressure regulator, cylinders, Manual pneumatics, Symbols of pneumatic valves, Design of manually operated circuits, control of multiple actuators, Electro pneumatics, Electrically actuated direction control valves, Relay control systems, Limit switches, pneumatic proximity sensors Design of pneumatic and electro pneumatic circuits.

References:

1. Milkell P. Groover, Automation, Production Systems and Computer Integrated Manufacturing, Kindle Edition, Prentice Hall of India, 2016.
2. S. Mukhopadhyay, S.Sen and A.K. Deb, Industrial Instrumentation, Control and Automation, Jaico Publishing House, 2013.

1. C. Roy, “Robots and Manufacturing Automation”, Asfahl John Wiley & Sons.
2. Krishna Kant, “Computer Based Industrial Control”, EEE-PHI, 2nd edition, 2010.
3. Viswanandham, ”Performance Modeling of Automated Manufacturing Systems”, PHI, 1st edition, 2009.
4. M.M.M. Sarcar, K. Mallikarjuna Rao, K. Lalit Narayan, Computer Aided Design and Manufacturing, Kindle Edition, PHI Learning, 2008.
5. Cundiff John S., and Kocher Michael F., Fluid Power Circuits and Controls, CRC Press, 2019.
6. Esposito Anthony, Fluid Power with Applications, Pearson Education Limited, 2013.
7. Ilango S., and Soundararajan V., Introduction to Hydraulics and Pneumatics, 2nd Ed., 2011.
8. Rabie Galal M., Fluid Power Engineering, McGraw Hill, 2009.
9. Johnson James, Introduction to Fluid Power,Delmar Thomson Learning, 2002.
10. Parr Andrew, Hydraulics and Pneumatics, Butterworth-Heinemann Ltd., 1991.

LEAN MANUFACTURING [3 1 0 4] [4 Credits]

Evolution of lean: Toyota Production System, lean principles development. Value definition: Customer value, value specification, value stream identification. **Waste elimination:** Seven wastes, waste identification techniques, root cause analysis. **Flow creation:** Production flow principles, cellular manufacturing, line balancing. Pull systems: Kanban systems, just-in-time production, and supplier integration. **Continuous improvement:** Kaizen philosophy, PDCA cycle, employee involvement. Standardized work: Work standardization, time studies, work instruction development. **Total productive maintenance (TPM):** Equipment effectiveness, preventive maintenance, autonomous maintenance. Lean metrics: Performance measurement, value stream metrics, continuous monitoring. **Implementation strategy:** Change management, training, sustainability.

References:

1. Womack, J.P., Jones, D.T., "Lean Thinking", Free Press
2. Monden, Y., "Toyota Production System", CRC Press
3. Liker, J.K., "The Toyota Way", McGraw Hill
4. Rother, M., Shook, J., "Learning to See: Value Stream Mapping", Lean Enterprise Institute

MECHANISM AND ROBOTICS [3 1 0 4] [4 Credits]

Introduction to robotics: types and specification of robots, DoF, configurations, control resolution, spatial resolution, accuracy and repeatability, actuators and sensors, drives, and transmission systems used in robotics. **Kinematic analysis & coordinate transformation**:Direct kinematic problem in robotics, homogeneous transformation matrices, joint space, and cartesian space, Denavit-Hartenberg method, Inverse manipulator kinematics solvability, robot kinematics constraints, robot workspace, holonomic robots, Jacobian matrix, Jacobian singularity. **Trajectory generation:** general considerations in the path description and generation, joint-space schemes, and cartesian-space schemes. Manipulator dynamics- Newton's equation, Euler's dynamic formulation, iterative vs. closed form. Mobile robot planning & navigation- Introduction, competencies for navigation-planning & reacting, obstacle avoidance. Navigation architecturesmodularity for code reuse & sharing, control localization, techniques for decomposition. Case studies on different robot configurations.

References:

1. Lynch, Kevin M. Modern Robotics-Mechanics, Planning, and Control: Video supplements and software. (2017).
2. Murray, Richard M. A mathematical introduction to robotic manipulation. CRC press, 2017.
3. Craig, John J. Introduction to robotics: mechanics and control. Vol. 3. Upper Saddle River, NJ, USA: Pearson/Prentice Hall, 2005.
4. Niku, Saeed. Introduction to robotics. John Wiley & Sons, 2010.
5. Mittal, R. K., and I. J. Nagrath. Robotics and control. Tata McGraw-Hill, 2003.

SMART MATERIALS AND SENSORS[3 0 0 3] [3 Credits]

Introduction of smart materials: Piezoelectric materials, magneto-strictive materials and magneto-resistance effect, electroactive materials and polymers, Shape memory alloys and polymers, electro and magneto rheological fluids, intelligent materials. **Piezoelectric Materials:** Piezoelectric effect, Constitutive equations, properties of piezoelectric materials, variation of coupling coefficients for PZT materials, **Mathematical modelling**: Electro mechanical performance. **Magneto-strictive Materials and Shape memory alloys:** Magneto-strictive Sensing Magneto mechanical coupling coefficients of magneto-strictive materials, constitutive relationships, Villari Effect, Matteuci Effect and Nagoka-Honda Effect, Magnetic Delay Line Sensing, Magneto strictive mini actuators. Classification of shape memory alloys, methods of fabrication, Control design for shape memory alloys and polymers, Electroactive polymers and its applications, LBHS and HBLS smart actuators. **Smart sensors:** Selection of sensors and its monitoring techniques for monitoring force, position, vibration, noise, temperature for the mechanical systems-Integrated and distributed temperature sensing, strain measurements, fluid rheological properties measurements using FBG and ultrasonic sensors, Application of accelerometers, EAP, SMAs, vision sensors, MEMS based actuators, robot sensors, micro sensors, Nano sensors, **Case studies and student presentations Structural Health Monitoring using Smart Sensors:** Structural integrity using fiber optic, acoustic/ultrasonic, and piezoelectric active sensors/patches, piezoelectric smart structures- numerical and experimental methods. Delamination sensing using magneto-strictive and Piezoelectric sensors. Case studies and student presentations.

References:

1. Victor Giurgiutiu, Structural Health monitoring with Piezoelectric Wafer Active sensors, Academic Press, 2008, 1st edition
2. Thompson and Gandhi, Smart Materials and Structures, Chapman and Hall, 1992
3. Alper Erturk and Daniel J Inmann, Piezoelectric energy harvesting, Wiley Publications, 2011, 1st edition
4. Krzysztof Iniewski, Smart sensors for industrial applications, CRC Press Taylor and Francis group, 2013.
5. Ananthasuresh, G. K., Vinoy, K. J., Gopalakrishnan, S., Bhat, K. N., and Aatre, V. K, Micro and Smart Systems: Technology and Modeling, Wiley, New York, 2012.

COMPUTER INTEGRATED MANUFACTURING SYSTEMS [3 0 0 3] [3 Credits]

CIM overview: Elements of CIM, manufacturing automation, integration technologies. **CAD/CAM integration:** Product design, process planning, NC programming. **Group technology:** Part families, classification and coding systems, cellular manufacturing. **Computer-aided process planning (CAPP):** Variant approach, generative approach, expert systems. Production planning and control: MRP, MRP-II, ERP systems. **Automated material handling:** Conveyors, AGV systems, AS/RS systems. Flexible manufacturing systems: FMS components, control systems, scheduling. **Quality control:** SPC, automated inspection, CMM integration. Communication systems: MAP/TOP protocols, networking in manufacturing. **Database management:** Manufacturing databases, data integration.

References:

1. Groover, M.P., "Automation, Production Systems, and Computer Integrated Manufacturing", Pearson
2. Singh, S., "Computer Aided Design and Manufacturing", Khanna Publishers
3. Koren, Y., "Computer Control of Manufacturing Systems", McGraw Hill
4. Rao, P.N., "CAD/CAM Principles and Applications", Tata McGraw Hill

SUPPLY CHAIN MANAGEMENT [3 0 0 3] [3 Credits]

Strategic Framework: Introduction to Supply Chain Management, Decision phases in a supply chain, **Process views of a supply chain:** push/pull and cycle views, Achieving Strategic fit, Expanding strategic scope. **Supply Chain Drivers and Metrics:** Drivers of supply chain performance, Framework for structuring Drivers, Obstacles to achieving strategic fit. **Designing**

Supply Chain Network: Factors influencing Distribution Network Design, Design options for a Distribution network, E-Business and Distribution network, Framework for Network Design Decisions, Models for Facility Location and Capacity Allocation. **Forecasting in SC:** Role of forecasting in a supply chain, Components of a forecast and forecasting methods, Risk management in forecasting. **Aggregate Planning and Inventories in SC:** Aggregate planning problem in SC, Aggregate Planning Strategies, Planning Supply and Demand in a SC, Managing uncertainty in a SC: Safety Inventory. **Coordination in SC:** Modes of Transportation and their performance characteristics, Supply Chain IT framework, Coordination in a SC and Bullwhip Effect.

References:

1. Supply Chain Management - Strategy, Planning and Operation, Sunil Chopra and Peter Meindl, Pearson Education Asia, 2010, 4th Edition.
2. Designing and Managing the Supply Chain - Concepts Strategies and Case Studies, David Simchi-Levi, PhilpKamintry and Edith Simchy Levy, Tata-McGraw Hill, 2000, 2nd Edition.
3. Managing Supply Chains A Logistics Approach', John J Coyle, Cengage Learning, 2013, 9th Edition.
4. Modeling the Supply Chain', Jeremy F Shapiro, Cengage Learning, 2007, 2nd Edition.

MECHANICS OF BULK METAL FORMING [3 0 0 3] [3 Credits]

Fundamentals of plasticity: Stress and strain relationships, yield criteria, flow rules. Material behavior: Work hardening, strain rate effects, temperature effects. **Forging analysis:** Upset forging, impression die forging, closed die forging. **Rolling processes:** Flat rolling, shape rolling, ring rolling, thread rolling. **Extrusion processes:** Forward extrusion, backward extrusion, impact extrusion, hydrostatic extrusion. **Drawing processes:** Wire drawing, tube drawing, deep drawing of sheets. Process modeling: Upper bound method, slip line field method, finite element analysis. **Defects in forming:** Surface defects, internal defects, dimensional variations. Tool design: Die design principles, tool materials, lubrication. **Industrial applications:** Automotive forming, aerospace applications, consumer products.

References:

1. Hosford, W.F., Caddell, R.M., "Metal Forming: Mechanics and Metallurgy", Cambridge University Press
2. Dieter, G.E., "Mechanical Metallurgy", McGraw Hill
3. Kumar, S., "Technology of Metal Forming Processes", Prentice Hall
4. Narayanasamy, R., "Metal Working Technology", Prentice Hall

FLEXIBLE MANUFACTURING SYSTEMS [3 0 0 3] [3 Credits]

Understanding of FMS: Evolution of Manufacturing Systems, FMS: Definition, objective and Need, FMS: components, Merits, Demerits and Applications, Flexibility in Pull and Push type. **Classification of FMS Layout:** FMS: Layouts and their Salient features, Single line, dual line, loop, ladder, robot centre type etc. **Salient features of processing stations:** Processing stations-Machining Centers, Turning centre, Coordinate measuring machine (CMM), Washing/ Deburring station. **MHS; An introduction:** Material Handling System Conveyor, Robots, Automated Guided Vehicle (AGV), Automated Storage Retrieval System (ASRS). **Management Technology:** Tool Management, tool magazine, Tool preset, identification, Tool monitoring and fault detection, FMS: Configuration planning and routing, FMS: Production Planning and Control, FMS: Scheduling and loading. Design of FMS: FMS: Performance Evaluation introduction, Analytical model of FMS, Simulation model of FMS. **Case studies:** Typical examples /case studies of FMS.

References:

1. William W Luggen, "Flexible Manufacturing Cells and System" Prentice Hall of Inc New Jersey, 1991
2. Reza A Maleki "Flexible manufacturing system" Prentice Hall of Inc New Jersey, 2012
3. "Manufacturing Systems Engineering" by Katsundo Hitomi. 2nd Edition (2017)
4. Groover,M.P "Automation, Production Systems and Computer Integrated Manufacturing", Prentice Hall of India Pvt.Ltd. New Delhi 2016

ADVANCED MATERIALS PROCESSING AND CHARACTERIZATION [3 0 0 3] [3 Credits]

Mechanical Behaviour of Materials & Engineering Alloys: Plastic deformation, strengthening mechanisms, damping properties of materials, fatigue & creep mechanisms Ferrous and nonferrous alloys used in engineering applications. **Modern Materials and Alloys:** Super alloys – Refractory metals - Shape memory alloys - Dual phase steels, Micro alloyed, High strength low alloy steel, Transformation induced plasticity (TRIP) steel. **Composite Materials:** Metals, ceramics and plastics based composites, processing techniques, types and applications. Advanced **Engineering Materials:** Metallic glasses, semiconductors, biomaterials as well as smart materials and nano engineered materials. Surface Modifications of Materials: Mechanical surface treatment and coating – coatings for improving the mechanical properties of material surfaces. **Characterization of Materials:** Hardness measurements – Conventional and Nano indentation, Optical microscopy, Scanning electron microscopy, Transmission electron microscopy principles, X-Ray diffraction and X-Ray Fluorescence. **Characterization of Surfaces:** Characterization of surface microstructure & properties, Measurement of coating thickness, Measurement of residual stress & stability, FTIR.

References:

1. Thomas H. Courtney, (2000), Mechanical Behavior of Materials, McGraw Hill.
2. Callister W.D. (2013), Material Science and Engineering- An introduction, Wiley – Eastern, 9th Edition.
3. Yinquan Yu, Sam Zhang (2022), Materials in Advance Manufacturing, 1st edition, CRC press.
4. Davis, J.R., (2001), Surface Engineering for corrosion and wear resistance, ASM International.
5. Raghavan, V. (2003), Physical Metallurgy, Prentice Hall of India.
6. Yang Leng (2008), Materials Characterization – Introduction to microscopic and spectroscopic methods, Wiley

BIG DATA ANALYTICS FOR MANUFACTURING [3 0 0 3] [3 Credits]

Introduction: Overview of DBMS - File vs DBMS - elements of DBMS - Relational Data Model - Introduction to relational model - Structure of relational mode – domain – keys - tuples to relational models - SQL – table creation - relationships - basic queries DML and DDL – Joins– Grouping. **Introduction to Big Data** : Types of Digital Data - Characteristics of Data – Evolution of Big Data - Definition of Big Data - Challenges with Big Data-3Vs of Big Data -Terminologies in Big Data - CAP Theorem - BASE Concept – NoSQL - Types of Databases – Advantages – NewSQL - SQL vs. NOSQL vsNewSQL - Introduction to Hadoop - Features – Advantages – Versions. **Overview of Hadoop Eco systems** : Hadoop distributions - Hadoop vs. SQL – RDBMS vs. Hadoop - Hadoop Components – Architecture – HDFS - Map Reduce: Mapper – Reducer - Map Reduce - Mapper – Reducer – Combiner – Partitioner - Hadoop 2 (YARN) - Architecture - Interacting with Hadoop Eco systems. No SQL databases - Cassandra: Introduction – Features - Data types – CQLSH - Key spaces - CRUD operations – Collections – Counter – TTL - Alter commands - Import and Export - Querying System tables.

References:

1. Seema Acharya, Subhashini Chellappa, "Big Data and Analytics", Wiley Publication, 2015.
2. Hurwitz JS, Nugent A, Halper F, Kaufman M. "Big data for dummies", John Wiley & Sons; 2013.
3. White T., "Hadoop: The definitive guide". O'Reilly Media, Inc."; 2012.
4. Bradberry R, Lubow E., "Practical Cassandra: a developer's approach", Addison-Wesley; 2013

VIRTUAL REALITY [3 0 0 3] [3 Credits]

Introduction to AR/VR/MR/XR: Augmented Reality, Virtual reality, Mixed Reality, Extended reality, History, Hardware and Software Integrated Development Environment, VR and AR 12 Devices, Temporal Resolution, Spatial Resolution, Motion Perception, Depth Perception, Colour Perception, Auditory, Perception, Haptics Perception, Locomotion Interfaces, VR display, Tracking, Rendering. **Unity3D and Unreal Engine:** Unity3D, Editor, Game Objects and Components, Materials, Texturing, Lighting, Package Import and Export, Modelling, Physics, Probuilder Modelling, Terrain Creation, Asset Store, Avatar Creation, Animator, Particle Systems, C# Scripting, AR Development Platform – Vuforia with Unity, AR Deployments using ARKit and ARCore, Workflow for Unreal Engine, Asset Libraries, Import functions, Plug-in Connection, Blueprint Workflows, Lighting and Shading. **Extended Reality:** XR Tool Kit Setup, Teleoperation, UI Interaction, XR Challenges: XR Best Methods and Process, HMD Oculus, UX Design, Quality Testing of XR Systems, XR Deployment Platform – Oculus / SteamVR / Open XR Deployment Platform Workflows –Test Cases.**AR-VR-MR-XR use cases**: Overview of use cases in Industry 4.0, Automobile Industry, Robotics, Manufacturing.

References:

1. Steven M. LaValle, Virtual Reality, 2016
2. Schmalstieg, D., & Höllerer, T. (2016). Augmented reality: Principles and practice. Pearson Education.
3. Aukstakalnis, S. (2016). Practical augmented reality: A guide to the technologies, applications, and human factors for AR and VR. Addison-Wesley Professional.

4. Vince, J. (2008). Virtual reality systems (1st ed.). Dorling Kindersley (India) Pvt. Ltd.
5. LaViola, J. J., Jr., Kruijff, E., McMahan, R. P., Bowman, D. A., & Poupyrev, I. (2017). 3D user interfaces: Theory and practice (2nd ed.). Addison-Wesley Professional.
6. Moshayedi, A. J., & Kolahdooz, A. (2023). Unity in embedded system design and robotics: A step-by-step guide.
7. Mather, G. (2016). Foundations of sensation and perception (2nd ed.). Routledge. 8. Mitch Mccaffrey, (2017), Unreal Engine VR Cookbook, Addison Wesley

RAPID TOOLING AND INDUSTRIAL APPLICATIONS [3 0 0 3] [3 Credits]

Rapid Prototyping and Tooling: Properties of Prototyping, Characteristics of Rapid Prototyping, Strategic Aspects for the use of Prototypes, Operational Aspects in the use of Prototypes, Applications of Rapid Prototyping in Industrial Product Development with Examples. Conventional Tooling Vs. Rapid Tooling. **Indirect Methods for Rapid Tool Production:** Classification of Rapid Tooling Methods. Role of Indirect Methods in Tool Production. Metal Deposition Tools, RTV Tools, Epoxy Tools, Ceramic Tools, Cast Metal Tools, Investment Casting, Fusible Metallic Core, Sand Casting, KeltoolTM Process. Case Studies. **Direct Methods for Rapid Tool Production:** Classification of Direct Rapid Tool Methods. Direct ACESTM Injection Moulds (AIMTM), Laminated Object Manufactured (LOM) Tools, DTM RapidToolTM Process: RapidSteel 1.0, RapidSteel 2.0, Copper Polyamide (PA). SandFormTM, EOS DirectToolTM Process, Direct Metal Tooling using 3DPTM, Topographic Shape Formation (TSF). Case Studies. **Aerospace and Defence Industry:** An Overview of AM Applications, AM as a Complete Value Chain. Aerospace Materials and their Requirements, Review of AM Technologies for the Aerospace Industry, Qualification and Certification of AM Parts, Design Considerations, Measurement of Feedstock Material Characteristics and Quality for Aerospace Alloys, The Processing and Heat Treatment of Super Alloys, Testing of Mechanical Properties, Surface Roughness and Fatigue Properties of Aero Parts, Non-destructive Evaluation of AM Parts, Aerospace Case Studies. **Medical and Dental Industry:** 3D Data Capture and Medical Scanning Technologies, Medical Image Processing Software Systems, Biomaterials, Virtual and Diagnostic Models, Planning and Simulation of Complex Surgeries, Design and Fabrication of Customized Implants and Prosthesis, Design and Production of Medical Devices, Tissue Engineering and Organ Printing, Medical Case Studies. **Automotive Industry:** Multi-material Manufacturing and prototyping, Making Cars with Ergonomic Hand-held Tools, Jigs and Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies. **Other Industrial Applications of AM:** Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and Architecture, Fashion and Textile, Jewellery Industry, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

References:

1. Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping & Rapid Tooling, D.T. Pham and S.S Dimov, Springer, 2001.
2. A Guide to Additive Manufacturing, Damir Godec, Joamin Gonzalez-Gutierrez, Axel Nordin, Eujin Pei, Julia Urena Alcazar, Springer, 2022.
3. Additive Manufacturing for the Aerospace Industry, Francis Froes, Rodney Boyer, Elsevier, 2019. 4. Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, Chua Chee Kai, Leong Kah Fai, 5th Edition. World Scientific, 2019.

5. Medical Modelling: The Application of Advanced Design and Rapid Prototyping Techniques in Medicine, Richard Bibb, Dominic Eggbeer and Abby Paterson, Woodhead, 2017.

6. Advanced Manufacturing Technology for Medical Applications, Ian Gibson, John Wiley, 2006. Reference Books:

7. Additive Manufacturing: 3D Printing for Prototyping and Manufacturing, Andreas ebhardt, JanSteffen Hötter, Hanser, 2016.

8. Rapid Prototyping, Tooling, and Manufacturing, A E W Rennie, C E Booking, D M Jacobson, Professional Engineering, 2002.

9. Rapid Tooling Technologies and Industrial Applications, Peter Hilton and Paul F Jacobs, Marcel Dekker Inc, New York, 2001.

10. Rapid Tooling Guidelines for Sand Casting, Wanlong Wang, Henry W. Stoll and James G. Conley, Springer, 2010.

11. 3D Printing in Medicine: A Practical Guide for Medical Professionals, Frak J. Rybicki, Gerald T. Grant, Springer, 2017.

12. Laser Additive Manufacturing: Materials, Design, Technologies, and Applications, Milan Brandt, Elsevier, 2017.

CYBER SECURITY IN MANUFACTURING [3 0 0 3] [3 Credits]

An overview of an industrial control system-the industrial control system architecture-the purdue model for industrial control systems- industrial control system communication media and protocols Industrial control system historymodbus and modbus TCP / IP – Profinet-Common IT protocols found in the ICS- Anatomy ICS attack scenario – Attacks-consequences-Risk assessment- Backend protocols-advanced metering infrastructure and smart gridIndustrial protocol simulators. **The converged plant wide Enterprise**-The safety zone-the manufacturing zone-the enterprise zone-the CPwE industrial network security framework- Physical ICS securityICS network security-ICS computer security-ICS Application security-ICS Device security - The ICS cyber security program development process. Introduction to industrial networking-common topologies- network segmentation-network services- Wireless networks-Remote access – performance considerations-safety instrumented systems-special considerations.

Consequences of successful cyber incident-cyber security and safety-common industrial targetscommon attack methods- Attack trends-industrial application layer attacks. Cyber security and risk management-methodologies for accessing risk within industrial control systemsystem characterization-threat identification-vulnerability identification-risk classification and ranking-risk reduction and mitigation**. Cyber physical systems** - Safety and security of cyber physical systems- Cyber-attacks and measures in cyber-physical systems - Cyber risks in industrial control systems - Costing security solutions -NERC CIP-CFATS-ISA/ IEC62443-mapping Industrial network security to compliance.

References:

1. Pascal Ackerman, “Industrial Cyber security-Efficiently secure critical infrastructure systems”, Packt Publishing Ltd., Bringham, 2017.

2. Eric D.Knapp and Joel Thomas Langill, “Industrial Network Security- Securing Critical Infrastructure Networks for smart Grid, SCADA, and other Industrial Control Systems” Syngress is an Imprint of Elsevier, 2015.
3. Lihui Wang, Xi Vincent Wang, “Cloud-Based Cyber –Physical systems in Manufacturing”, Springer Nature, 2018
4. Edward J.M. Colbert and Alexander Kott, “Cyber-Security and SCADA and other Industrial control Systems” Springer International Publishing AG Switzerland, 2016

QUALITY CONTROL AND RELIABILITY [3 0 0 3] [3 Credits]

Introduction to quality: Definitions of quality, quality management systems, cost of quality. **Statistical process control:** Control charts for variables (X-bar, R, S charts), control charts for attributes (p, np, c, u charts). **Process capability:** Capability indices (Cp, Cpk, Pp, Ppk), process capability studies. **Acceptance sampling:** Single sampling plans, double sampling plans, operating characteristic curves. **Reliability engineering:** Reliability functions, failure rate, mean time between failures (MTBF). **Life testing:** Life test planning, accelerated life testing, Weibull analysis. System reliability: Series systems, parallel systems, k-out-of-n systems. **Failure mode and effects analysis (FMEA):** Process FMEA, design FMEA, risk priority numbers. **Six Sigma methodology:** DMAIC process, statistical tools, project management.

References:

1. Montgomery, D.C., "Introduction to Statistical Quality Control", John Wiley & Sons
2. Grant, E.L., Leavenworth, R.S., "Statistical Quality Control", McGraw Hill
3. Juran, J.M., Gryna, F.M., "Quality Planning and Analysis", McGraw Hill
4. Lewis, E.E., "Introduction to Reliability Engineering", John Wiley & Sons

RENEWABLE ENERGY TECHNOLOGY [3 0 0 3] [3 Credits]

Energy scenario: Global and Indian energy scenario, renewable energy potential. **Solar energy:** Solar radiation, photovoltaic cells, solar thermal systems, concentrated solar power. **Wind energy:** Wind resource assessment, wind turbine aerodynamics, wind power systems. **Biomass energy:** Biomass resources, conversion technologies, biogas production, biofuels. **Hydropower:** Small hydropower systems, micro-hydro technology, pump storage systems. Geothermal energy: Geothermal resources, power generation systems, heat pump applications. **Ocean energy:** Tidal energy, wave energy, ocean thermal energy conversion (OTEC). Energy storage: Battery systems, pumped storage, compressed air storage. **Grid integration:** Smart grids, power quality issues, energy management systems. **Economic analysis:** Cost analysis, life cycle assessment, policy frameworks.

References:

1. Khan, B.H., "Non-Conventional Energy Resources", Tata McGraw Hill
2. Boyle, G., "Renewable Energy", Oxford University Press
3. Kothari, D.P., Singhal, K.C., Ranjan, R., "Renewable Energy Sources and Emerging Technologies", PHI
4. Sukhatme, S.P., Nayak, J.K., "Solar Energy: Principles of Thermal Collection and Storage", Tata McGraw Hill

Laboratory Facility

Students who enroll in the Virtual Proto Typing and Digital Manufacturing programs have remote access to the labs in the areas of manufacturing. These labs play a vital role in enhancing student engagement and enriching the "learning by doing"- cornerstone of digital manufacturing programs.

Laboratory Architecture

- The lab is organized around three engineering domains such as, design, materials, manufacturing, and operations
- The structured lab exercises are packaged as simulation-capsules that guide the students through a sequence of practice problems of increasing complexity eventually to build the competency to solve an industry scale problem
- Students required to perform experiments as a part of their course work in their respective lab assigned.

Laboratory Outcomes

- On completion of the experiment, students should submit the report for evaluation.
- Apply the gained knowledge in solving creative industry scale problems

Industrial Internet of Things

[3 0 0 3] [1 Creditis]

An Industrial Internet of Things (IIoT) Lab is a specialized environment where organizations develop, test, and refine IIoT technologies and solutions for industrial applications. These labs provide hands-on access to equipment and space for experimentation, IIoT labs facilitate research, project development, and the creation of smart, connected systems for businesses.

List of Experiments

- Interfacing On Board Cathode RGB LED with Pico Control using thingZkit IoT
- Interfacing Pull-Up Push Button with Pico Control using thingZkit IoT
- Interfacing On Board Pull-Down Push Button with Pico Control using thingZkit IoT
- Interfacing Onboard Buzzer with Pico Control using thingZkit IoT
- Interfacing Onboard Slide Switch with Pico Control using thingZkit IoT
- Interfacing Onboard Relay Control with Pico on thingZkit IoT
- Interfacing Onboard Potentiometer Voltage Control with Pico on thingZkit IoT
- Interfacing Onboard IR Sensor with Pico on thingZkit IoT
- Interfacing Onboard Ultrasonic Sensor with Pico on thingZkit IoT
- Interfacing Onboard LM35 Temperature Sensor with Pico on thingZkit IoT

Laboratory Outcomes

Industrial Internet of Things (IIoT) Lab learning outcomes focus on practical skills, enabling learners to design and build IIoT systems, interface with sensors and actuators, develop cloud-based solutions, analyze IIoT data, and gain hands-on experience with hardware platforms. The goal is to equip students with the knowledge to analyze industrial problems, develop innovative IIoT solutions, and understand the workflow of industrial IoT systems.

Advanced Material Testing Lab

[3 0 0 3] [1 Creditis]

An "Advanced Materials Testing Lab" refers to a laboratory that uses a variety of analytical and testing techniques to determine the physical, mechanical, chemical, and structural properties of materials, and mechanical testing methods to evaluate material performance for quality assurance, product development, and failure analysis.

List of Experiments

- Heat treatment of Metal/alloys.
- Microstructural analysis of Metal/alloys.
- Mechanical Characterization of Metal/alloys.
- Tribological Characterization of Metal/alloys.
- Nondestructive testing
- Machinability characterization of Metal/alloys under two-high hand operated rolling mill,
   Processing and characterization of composite material using Autoclave.

Laboratory Outcomes

Learning outcomes for an Advanced Materials Testing Lab focus on enabling students to analyze material properties, select appropriate characterization techniques, operate and troubleshoot equipment (e.g., microscopy, spectroscopy, diffraction), interpret complex data, and apply this knowledge to real-world problems in materials science and engineering.

Manufacturing Control and Automation Lab

[3 0 0 3] [1 Credits]

Manufacturing Control and Automation Lab mainly focuses on the principles and practical application of manufacturing automation, possibly including topics like PLCs, SCADA systems, robots, and industrial control, which help streamline processes, reduce costs, and improve quality in manufacturing.

List of Experiments

- Pneumatic controls: Pneumatic components and their application circuits.

- Electro-pneumatic application circuits. components, and their Hydraulic controls:
- Hydraulic and electrohydraulic components and their application circuits.

Laboratory Outcomes

Learning outcomes for a Manufacturing Control and Automation Lab include understanding automation concepts and its relevance to manufacturing, gaining knowledge of hard and soft automation, implementing industrial control systems and PLCs, data acquisition and analysis for process optimization, and applying concepts of Industry 4.0 technologies like IoT and AI to automate manufacturing processes.

Additive Manufacturing Virtual Lab

[3 0 0 3] [1 Credits]

Additive manufacturing lab mainly focuses on 3D printing and advanced fabrication space, covering topics such as the definition of additive manufacturing (3D printing), the different processes involved (like powder bed fusion and material extrusion), and the typical steps in the additive manufacturing workflow, from digital design to post-processing.

List of Experiments

- 3D modelling using Autodesk Fusion 360
- Generative Design using Autodesk Fusion 360
- Process planning in FDM using Ultimaker Cura and Creality Print
- Process simulation and Material analysis.
- 3D printing part orientation optimization.
- Predict stress and distortion on the AM process.
- FDM Anatomy of 3D Printer Machine
- Cartesian 3D Printer Machine
- Polar 3D Printing machine
- Delta 3D Printing machine
- Simulation of Stereolithography Process
- Simulation of Fused Deposition Modelling (FDM) Process
- Simulation of Selective Laser Sintering (Non-Metal) Process
- Simulation of Selective Laser Sintering (Metal) Process
- Simulation of Laminated object manufacturing Process

- Simulation of Powder Binding / Jetting Process
- Simulation of Post-processing in Additive manufacturing
- Simulation of Pre-processing in Additive manufacturing

Laboratory Outcomes

Additive Manufacturing Lab learning outcomes include understanding various AM processes, selecting appropriate processes and materials for specific parts, designing parts with additive manufacturing principles in mind (including support structures and build orientation) and applying knowledge to design and fabricate functional prototypes.

Mechanism and Robotics Virtual Lab

[3 0 0 3] [1 Credits]

Mechanism and Robotics Virtual lab focuses on the design, analysis, and application of mechanical systems. Mechanisms are the fixed-motion components within these systems, while robots are programmable machines that use mechanisms to perform autonomous or semi-autonomous tasks.to solve robotic arm problems.

List of Experiments

- Introduction to Raspberry Pi programming.
- IR sensor data and glow LEDs using Raspberry Pi.
- Ultrasonic sensor data using Raspberry Pi.
- Control of servo motor actuators using Raspberry Pi.
- Control of DC motor actuators using Raspberry Pi.
- Read sensor data with Arduino
- Control of servo motor actuators using Arduino Color detection using OpenCV.
- Shape detection using OpenCV
- Biscuit Quality detection using OpenCV
- Robot Studio: Using the library tool trace a square. IRB (Online Programming): Jogging and tracing a square.

- Robot Studio: Create a custom tool and trace a circle with auto path. IRB (Online Programming): Pick and place a single object/ multiple objects.
- Implementation of safety features in COBOT
- Universal Robots UR5 collaborative robot: Introduction, defining tool center point, implementation of pick and place operation
- Universal Robots UR5 collaborative robot: Implementation of destacking and stacking operation
- Read DH-parameters and obtain the transformation matrix (Using Python)
- Mini Project using Raspberry Pi/ Arduino/ OpenCV/ Robot Studio/Cobo
- Modelling, offline programming and simulation of a 5-Axis Robot manipulator
- Programming and operation of a 5-Axis Robot manipulator

Laboratory Outcomes

Learning outcomes for a Mechanisms and Robotics lab include identifying geometric relationships in robotic arms, formulating coordinate transformation matrices, creating 3D workspace plots, analyzing robot motion from joint angles, interpreting simulation results for mechanisms, and applying kinematics to solve robotic arm problems.

Flexible Manufacturing Systems Virtual Lab

[3 0 0 3] [1 Credits]

The Flexible Manufacturing System Virtual lab introduces both Conventional and NonConventional metal cutting. Programming is performed in the lab for various machining operation.

List of Experiments

- CNC Conventional Machining
- Die Sink Electric Discharge Machining
- Wire Electric Discharge Machining
- Laser Beam Machining of Metals/Alloys
- Abrasive Water Jet Machining
- Modeling and Simulation of Computer Integrated Manufacturing System

- Modelling, Offline Manual Part Programming and Simulation of the operation of a 3 axis CNC Milling Machine
- Programming and operation of a 3 axis CNC Miling Machine
- CAD/CAM based Part Programming and operation of a 3 axis CNC Milling Machine

Laboratory Outcomes

Flexible Manufacturing Systems Virtual (FMSV) Lab learning outcomes enable students to analyze and design automated manufacturing processes, understand concepts like group technology, material handling, and numerical control, and evaluate the economic feasibility of implementing flexible systems.

Laboratory Facilities Available

Flexible Manufacturing Systems Virtual (FMSV) Lab learning outcomes enable students to analyze and design automated manufacturing processes, understand concepts like group technology, material handling, and numerical control, and evaluate the economic feasibility of implementing flexible systems.

The Lab Facilities for proposed M.Tech in Virtual Proto Typing and Digital Manufacturing Programme already available in Mechatronics, Aeronautical, Mechanical and Industrial Engineering

- Industrial Internet of Things Lab (Mechatronics Engineering Department)
- Advanced Materials Testing Lab(Aeronautical, Mechanical and Industrial Engineering Department)
- Manufacturing Control and Automation Lab (Mechatronics Department)
- Additive Manufacturing Virtual Lab(Mechanical and Industrial Engineering Department)
- Mechanism and Robotics Virtual Lab(Mechatronics Department)
- Flexible Manufacturing Systems Virtual Lab(Mechanical and Industrial Engineering Department)
- Virtual Lab available through Online Mode (https://3dp-dei.vlabs.ac.in/ and http://vlabs.iitkgp.ac.in/cim/)

Available Laboratory Equipment:

Industry Collaboration

- Student Internship
- Training Programmes
- Knowledge Exchange
- Possible Joint Projects.
- Placements
- Research Consultancy

List of Collaborative Company Approached

- Bosch Ltd
- Planet Power Tools Private Limited

- Starcke Abrasives Private Limited
- PERIDOT Advanced Materials Private Limited
- Larsen and Turbo Limited
- ICSOFT
- VOLVO Group India
- Rimtex Engineering Private Ltd
- CMTI
- CIPET
- ACE Micromatics

Mode of Examination

- Mode of Examinations applicable for students admitted.
- Semester 1 and 2 have Mid-Semester Examinations and End Semester Examinations for each course. Students need to appear in person for taking the examinations at the institution's designated examination schedule.
- In Semester 3 and 4, the student will be doing Dissertation/Project Work as per the Institution's guidelines.