Scheme and Syllabus for

M.Tech. in

Smart Manufacturing

Scheme/Structure for
M.Tech in Smart Manufacturing

Semester I						
S. No.	Course Code	Course Name	Category	I	P	C
1		Scientific Computing	PEC	2	2	3
2		Applied AI for Manufacturing	PEC	3	3	5
3		Mechatronic Product Design	PEC	3	3	5
4		Advanced Manufacturing Processes	PEC	3	3	5
5		Elective-I	PEC	3	0	3
6		Seminar	PCD	0	3	2
Total				14	14	23
Semester II						
S. No.	Course Code	Course Name	Category	I	P	C
1		Industrial IoT and Cloud Computing	PEC	3	3	5
2		Modelling and Simulation of Manufacturing Systems	PEC	3	3	5
3		Micro and Nano Manufacturing Technology	PEC	3	3	5
4		Elective-II	PEC	3	0	3
5		Elective-III	PEC	3	0	3
6		Comprehensive Viva-Voce	PEC	2	0	2
Total				17	9	23
Semester III						
1		Dissertation Work-I	PCD	0	25	10
2		Skill development course-I	PEC	3	0	Pass/ Fail
Total				0	25	15
		Semester IV				
1		Dissertation Work-II	PCD	0	25	15
Total				0	25	15

Grand total number of credits for M.Tech = 76

Course Title	Course Code	Structure (I-P-C)		
Scientific Computing		**2**	**2**	**3**

Pre-requisite, if any: Nil.

Course Outcomes: At the end of the course the students will be able to:

CO1	Solve the system of linear equations and eigenvalue problems numerically.
CO2	Solve numerically algebraic/transcendental equations.
CO3	Interpret experimental data using interpolation.
CO4	Apply numerical integration methods to evaluate the definite integral.
CO5	Find the numerical solutions of ODEs and PDEs.

Syllabus:

Numerical Methods in Linear Algebra: Direct and iterative solution techniques for simultaneous linear algebraic equations – Gauss elimination, Gauss-Jordon, LU Decomposition, QR Method, Jacobi and Gauss-Seidel Methods, Eigenvalues and Eigenvectors, Power and inverse power method, physical interpretation of eigenvalues and eigenvectors.

Solution of Algebraic and Transcendental Equations: Solution of nonlinear algebraic equations: Bisection method, fixed-point iteration method, Newton-Raphson, Secant method, solution of system of nonlinear algebraic equations

Interpolation: Polynomial interpolation, Lagrange interpolating polynomial, Hermite interpolation, Cubic Spline interpolation, interpolation in 2 and 3 dimensions.
Numerical Differentiation and Integration: Finite difference formula using Taylor series, Differentiation of Lagrange polynomials, Simpson's rule, Gauss-quadrature rule, Romberg method, multiple integrals.

Numerical Solution of Differential Equations: Ordinary Differential Equations – Euler, Heun's method and Stability criterion, second order and fourth order Runge-Kutta methods, Adams-Bashforth-Moulton method, system of ODEs, Finite difference method for ODE, Partial Differential Equations – Classification of PDEs, Elliptic equations, Parabolic equations (Transient diffusion equation), Hyperbolic equations (wave equation)

Text Book(s) and References:

1. David Kincaid and Ward Cheney, "Numerical Analysis: Mathematics of Scientific Computing'', AMS, 2009.
2. Richard L. Burden and J. Douglas Faires, Numerical Analysis, Cengage Learning India Private Ltd.
3. M. K. Jain, S.R.K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publications, 2008.
4. K. E. Atkinson, "An Introduction to Numerical Analysis", Wiley, 2nd Edition, 1989.
5. S.D. Conte, Carl de Boor, "Elementary Numerical Analysis: An Algorithmic Approach'', SIAM, 2018.

Course Title	Course Code	Structure (I-P-C)		
Applied AI for Manufacturing		**3**	**3**	**5**

Pre-requisite, if any: Basic Concepts of Manufacturing Processes

Course Outcomes: At the end of the course the students will be able to:

CO1	Understand the capability of AI for production planning and decision making.
CO2	Understand the fundamental concepts of manufacturing scheduling and role of robot control system in manufacturing
CO3	Realize application of Machine Learning to Industrial Planning and Decision Making
CO4	Develop a practical understanding of effective scheduling.
CO5	Develop Integrated Software System for Intelligent Manufacturing and Planning for Robot Control Systems in Manufacturing.

Syllabus:
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,

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.

Practice:
These Laboratory classes aims at:
1. Understanding the phenomena involved
2. Study of influencing parameters
3. Develop setup, instrumentation, equation, product, etc.
4. Modelling & Simulation of the process
5. Simple project
6. Creation of concept
7. Application to real problem

8. Assignments suggested by the instructor.

Text Book(s) and 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.

Course Title	Course Code	Structure (I-P-C)		
Mechatronics Product Design		**3**	**3**	**5**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Understand the basic concepts of the main sensors used in electromechanical systems
CO2	Understand the fundamental concepts of mechanical power transmission components, and pneumatic and hydraulic actuators
CO3	Use the common analogue and digital interfaces between sensors/actuators and the systems under control using open-source microcontrollers
CO4	Understand the integration of mechanisms, sensors, actuators, interfaces and software in the design of mechatronic systems.
CO5	Understand basics of open source hardware/software, Mechaphonics, and mobile/web apps
CO6	Hands-on laboratory experiments and team projects involving the above concepts.

Syllabus:
Introduction: Mechatronics, history, applications, and trends.

Sensors and transducers: Characterization, sensors for position, velocity, proximity, force, pressure, temperature and light.

Signal conditioning: Amplification, filtering, multiplexing, and telemetry. Data acquisition with A/D, D/A and digital I/O.

Mechanical components: Types of motion, kinematic chains, cams, gears and other power transmission mechanisms.

Software development: program structures for embedded systems, software design process, inter-processor communication, microcontrollers and peripherals.

Pneumatic and hydraulic actuators: Basics of fluid flow, control valves, cylinders and rotary actuators for pneumatics and hydraulics.

Microcontrollers: Introduction to use of open-source hardware (Arduino & Raspberry Pi); shields/modules for GPS, GPRS/GSM, Bluetooth, RFID, and Xbee, integration with wireless networks, databases and web pages.

Basic closed-loop control: open-loop, on-off, PID control, Mechatronic systems integration, rapid prototyping of mechanical and electrical systems. Demonstrations of mechatronic systems in class.

Practice:
These Laboratory classes aim at:
1. Arduino microcontroller I/O and interfacing
2. Basic sensors interfacing with Arduino
3. GPS and data logging with Arduino

4. Networking with Arduino: GSM and Bluetooth
5. Raspberry Pi microcomputer I/O and interfacing
6. Simple project
7. Creation of concept
8. Application to real problem
9. Assignments suggested by the instructor.

Text Book(s) and References:

1. J. Edward Carryer, et al., Introduction to Mechatronic Design, Prentice Hall, 1st edition, 2010, ISBN: 978-8131788257.
2. W. Bolton, Mechatronics, Pearson India, 4th edition, 2010, ISBN: 978-8131732533.
3. D. G. Alciatore and M. B. Histand, Introduction to Mechatronics and Measurement Systems, McGraw-Hill, 4th edition, 2014, ISBN: 978-9339204365.

Course Title	Course Code	Structure (I-P-C)		
Advanced Manufacturing Processes		**3**	**3**	**5**

Pre-requisite, if any: Basic Concepts of Manufacturing Processes

Course Outcomes: At the end of the course the students will be able to:

CO1	Model the material removal in various advanced manufacturing processes.
CO2	Analyze the processes and evaluate the role of each process parameter during machining of various advanced materials.
CO3	Realize products using advanced manufacturing processes
CO4	Develop a practical understanding of advanced manufacturing processes and capabilities of each.
CO5	Identify and rectify defects in parts and manufacturing processes related problems.
CO6	Analyze data from experiments performed and reach conclusions.

Syllabus:

INTRODUCTION TO ADVANCED MANUFACTURING PROCESSES:

Introduction to manufacturing processes. Overview of non-conventional machining processes with (AJM, USM, ECM, EDM, EBM, LBM, AFM, MRF, MAF, MFP and MRAFF etc.). Introduction to use of non-conventional processes for micro-machining.

MECHANICAL MATERIAL REMOVAL PROCESSES:

Abrasive Jet Machining (AJM) – Introduction, process parameters, estimation of MRR and Modeling of MRR. Components of AJM and Numerical approach.

Water Abrasive jet machining (WAJM): Basic principle, estimation of MRR WAJM process video.

Ultrasonic Machining (USM) – Introduction, process parameters, estimation of MRR, modeling of MRR. Design of acoustic ultrasonic head and feed mechanism in USM. Numerical approach.

ELECTROCHEMICAL MACHINING PROCESS:

Electrochemical Machining (ECM): Basic Principle, Estimation of MRR, MRR in multiphase alloys, Modeling of Kinematics and Dynamics for ECM process, Tool design, Surface Finish and Numerical approach.

Different Electrochemical Machining: Grinding, drilling, Milling, Turning and boring (basic principle and process parameters)

THERMAL MATERIAL REMOVAL PROCESSES:

Electro-discharge machining (EDM): Basic Principle, Process parameters, Estimation of MRR, Modeling of depth of melting temperature, Role of cavitation and melting temperature of the work-piece material, Surface finishing and machining accuracy Electrode and dielectric fluid, EDM turning and Wire EDM. **Electron Beam Machining (EBM):** Introduction, Comparison of E-beam machining with other thermal processes, Setup for EBM, Power requirement in E-Beam, Mechanics of EBM process, Derivation of functional characteristics in EBM by using Buckingham's Pie theorem.

Laser Beam Machining (LBM): Introduction, types of lasers and feedback mechanisms, MRR, Numerical modeling on semi-infinite surface and with circular beams, Estimation of machine time, Steady state hole penetration model in LBM.

Practice:

These Laboratory classes aim at:

1. Understanding the phenomena involved

2. Study of influencing parameters
3. Develop setup, instrumentation, equation, product, etc.
4. Modelling & Simulation of the process
5. Simple project
6. Creation of concept
7. Application to real problem
8. Assignments suggested by the instructor.

Text Book(s) and References:

1. Advanced manufacturing processes, Hassan Abdel, Gabad El Hoffy, McGraw Hill.
2. V.K.Jain, Advance Machining Processes, Allied Publisher Bombay.
3. Ghosh and Mallik, Manufacturing Science, EWP Private Ltd.
4. Pandey P.C., Shan H.S., Modern machining processes, Tata McGraw-Hill Education
5. Weller E.J., Nontraditional machining processes, Society of Manufacturing Engineers, Publications.

Course Title	Course Code	Structure (I-P-C)		
Industrial IoT and Cloud Computing		**3**	**3**	**5**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Understand the existing IoT architectures
CO2	Design an IoT system with cloud infrastructure
CO3	Implement a prototype of the IoT/cloud system design
CO4	Understand the existing cloud architectures

Syllabus:
Introduction, Physical design of IoT, Logical design of IoT, IoT enabling technologies, Domain specific IoTs IoT design methodology, logical design

IoT physical devices (such as Raspberry Pi, pcDuino, Beaglebone black, Cubieboard)
Introduction to cloud computing: cloud models, cloud service examples, cloud based services & applications

Virtualization, load balancing, scalability, deployment, replication, monitoring, SDN, network function virtualization, MapReduce, identity and access management, SLAs.

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, Open source private clouds.

Case studies: Industrial automation, Cloud for IoT

Practice:
These Laboratory classes aim at:
1. Understanding the phenomena involved
2. Study of influencing parameters
3. Develop setup, instrumentation, equation, product, etc.
4. Modelling & Simulation of the process
5. Simple project
6. Creation of concept
7. Application to real problem
8. Assignments suggested by the instructor.

Practice: (practice exercises can be mini projects)
Using IoT devices small systems like classroom automation, smart parking, environment monitoring can be designed and implemented. Also, hadoop cluster can be set up and studied. Cloud computing with IoT for healthcare and industrial automation can be studied

Text Book(s) and References:

1. A. Bahga and V. Madisetti, Internet of Things, A hands-on approach, CreateSpace Independent Publishing Platform, 1st edition, 2014, ISBN: 978-0996025515.

2. A. Bahga and V. Madisetti, Cloud Computing, A hands-on approach, CreateSpace Independent Publishing Platform, 1st edition, 2013, ISBN: 978-1494435141
3. S. Jeschke, C. Brecher, H. Song, and D. B. Rawat, Industrial Internet of Things: Cybermanufacturing Systems, Springer, 1st edition, 2017, ISBN: 978-3319425580.
4. T. Erl, Z. Mahmood, and R. Puttini, Cloud Computing: Concepts, Technology & Architecture, Prentice Hall, 1st edition, 2013, ISBN: 978-0133387520.

Course Title	Course Code	Structure (I-P-C)		
Modelling and Simulation of Manufacturing Systems		**3**	**3**	**5**

Pre-requisite, if any: Basics of simulation and modelling

Course Outcomes: At the end of the course the students will be able to:

CO1	Design and evaluate a given manufacturing system using simulation.
CO2	Generate random numbers and variants to execute a simulation model; and Modelling of statistical analysis and report generation
CO3	Evaluate queuing networks and markov chains in the context of manufacturing
CO4	Design a complete range of statistical distribution options to accurately model process variability.
CO5	Develop object paths and routes for simulation and
CO6	Realistic 2D and 3D animation capabilities to visualize results beyond numbers and Analyse Performance metrics and dashboards

Syllabus:

Introduction to System and simulation: Concept of system and elements of system, Discrete and continuous system, Models of system and Principles of modeling and simulation, Monte carlo simulation, Types of simulation, Steps in simulation model, Advantages, limitations and applications of simulation, Applications of simulation in manufacturing system.

Review of statistics and probability: Types of discrete and continuous probability distributions such as Geometric, Poisson, Uniform, Geometric distribution with examples, Normal, Exponential distribution with examples

Random numbers: Need for RNs, Technique for Random number generation such as Mid product method, Mid square method, and Linear congruential method with examples
Test for Random numbers: Uniformity - Chi square test or Kolmogorov Smirnov test, Independency- Auto correlation test

Random Variate generation: Technique for Random variate generation such as Inverse transforms technique or Rejection method
Analysis of simulation data: Input data analysis, Verification and validation of simulation models, Output data analysis

Simulation languages: History of simulation languages, Comparison and selection of simulation languages
Design and evaluation of simulation experiments: Development and analysis of simulation models using simulation language with different manufacturing systems

Practice:

Predict the course and results of certain actions. Gain insight and stimulate creative thinking. Visualize your processes logically or in a virtual environment.

Identify problem areas before implementation. Explore the potential effects of modifications. Confirm that all variables are known.

Optimize your operations. Evaluate ideas and identify inefficiencies. Understand why observed events occur. Communicate the integrity and feasibility of your plans.

Improve visibility into the effect of a system or process change. Explore opportunities for new procedures or methods without disrupting the current system. Diagnose and fix problems. Reduce or eliminate bottlenecks

Reduce operating costs. Improve financial forecasting. Better assess hardware and software requirements. Reduce delivery times. Better manage inventory levels, personnel, communications systems, and equipment. Increase profitability through overall improved operations.

Text Book(s) and References:

1. Jerry Banks, John S. Carson, Barry L. Nelson, David M. Nicol, and P. Shahabudeen, Discrete Event System Simulation, PHI, New Delhi, 2008.
2. Averill M. Law and W. David Kelton, Simulation Modeling and Analysis, Tata McGraw Hill, New Delhi, 2006.
3. N. Viswanadham and Y. Narahari, "Performance Modeling of Automated Manufacturing Systems", PHI, New Delhi, 2007.

Course Title	Course Code	Structure (I-P-C)		
Micro and Nano Manufacturing Technology		**3**	**3**	**5**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Model the material removal in various micro manufacturing processes.
CO2	Analyze the processes and evaluate the role of each process parameter during machining of various advanced materials.
CO3	Select the best process out of the available various advanced manufacturing processes for the given job assignment.
CO4	Understand requirements to achieve maximum material removal rate and best quality of machined surface while machining various industrial engineering materials.
CO5	Assess the difference between macro and micro machining process
CO6	Predict appropriate parameter for optimum machining and better product quality

Syllabus:

Introduction: Introduction to the Course & Classification of Micromanufacturing Processes. Challenges in Meso-, Micro-, and Nanomanufacturing.

Introduction to Traditional and Advanced Micromachining Processes: Microturning, Micromilling, Microgrinding, Biomachining, Micro- and Nano-manufacturing by Focused Ion Beam, Electric discharge micromachining, Electrochemical micromachining, Abrasive water jet micromachining.

Microcasting and Micromolding: Microcasting, Micromolding – A soft Lithography Technique.

Microforming: Introduction to Microforming, Micro- and Nanostructured Surface Development by Nano Plastic Forming and Roller imprinting, Microextrusion, Microbending with Laser.

Microjoining: Introduction to microjoining, Laser Microwelding, Electron Beams Microwelding and Applications. Fabrication of Microelectronic Devices.

Nanofinishing: Magnetorheological and Allied Finishing Processes and their theoretical analysis, Theoretical Analysis of Abrasive Flow Finishing, An Integrated Wafer Surface Evolution Model for Chemical Mechanical Planarization (CMP).

List of suggested experiments:

1. Experimental study on micro turning
2. Experimental study on micro milling
3. Experimental study on micro drilling
4. Investigation on micro machining under Minimum Quantity Lubrication (MQL) condition
5. Ultrasonic machining
6. Experiments on Electrochemical machining
7. Experiments on Electrodeposition

Text Book(s) and References:

1. Micromanufacturing, V. K. Jain (Ed.), CRC press, 2012.
2. Micromanufacturing & Nanotechnology, N. P. Mahalik, Springer.
3. Microfabrication & Nanomanufacturing, Mark J. Jackson, CRC press.
4. Introduction to Micromachining, V. K. Jain (Ed.), Narosa publisher, 2010.
5. HMT, Production Technology. Tata McGraw Hill, 2004.
6. ASTME, Tool Engineer's Handbook
7. E. P. DeGarmo, J. T. Black, and R. A. Kohser, "DeGarmo's materials and processes in manufacturing", John Wiley & Sons,2011.
8. M. P. Groover, "Principles of Modern Manufacturing", 5th Edition, Wiley, 2014
9. S. Kalpakjain, and S. R. Schmid, "Manufacturing processes for engineering materials", 5th Edition, Pearson Education, 2010.
10. W. A. J. Chapman, Workshop Technology, Vol. 2 & 3. CBS Publishers & Distributors, 1980.
11. N. K. Mehta, Machine Tool Design and Numerical Control, 2^{nd} ed. Tata McGraw Hill, 1996

Course Title	Course Code	Structure (I-P-C)		
Comprehensive Viva-Voce		**3**	**0**	**3**

Pre-requisite, if any:

Course Outcomes: At the end of the course the students will be able to:

CO1	Students will be able to demonstrate a thorough understanding of the subjects in the course.
CO2	Students will be able to think critically and solve problems related to the subjects in the course.
CO3	Students will be able to communicate their ideas clearly and effectively.

Syllabus:

I. Introduction

- Comprehensive Viva-Voce would be conducted towards end of the second semester on the subjects that were taught to the students. Each one would be asked to identify their topic of interest to present to the panel; however, the Question-Answer session would be on the subjects that were covered along with individual elective subject(s).

II. Presentation (15- 30 minutes)

- Each student will give a brief presentation on a topic covered in the course.
- The presentation will be followed by questions from the panel.

III. Question-Answer Session (15-30 minutes)

- The panel will ask questions to each student, related to the subjects in the course.
- The questions will be designed to assess the students' understanding, critical thinking, and problem-solving skills.

IV. Feedback and Evaluation (5-10 minutes)

- The panel will provide feedback to each student on their performance in the comprehensive viva-voce.
- The panel will evaluate each student's performance based on their understanding of the subjects in the course, critical thinking, problem-solving skills, and communication abilities.

V. Conclusion (5 minutes)

- Summarize the purpose and importance of the comprehensive viva-voce.
- Thank the students for their participation.

Assessment Method:

- Each student will be assessed based on their understanding of the course material, critical thinking, problem-solving skills, and communication abilities.
- The panel will provide feedback to each student on their performance in the comprehensive viva-voce.
- The results of the comprehensive viva-voce will be recorded and will contribute to the overall grade for the course.