CURRICULUM & SYLLABI

for

M. Tech Programme

in

Mechanical Engineering

(Intelligent Mechanical Systems)

(2026 Onwards)

DEPARTMENT OF MECHANICAL ENGINEERING

National Institute of Technology Manipur

Langol, Imphal- 795004

India

Department of Mechanical Engineering राष्ट्रीय प्रौद्योगिकी संस्थान मणिपुर
NATIONAL INSTITUTE OF TECHNOLOGY, MANIPUR
Langol, Imphal-795004. Email:- hodmechanical@nitmanipur.ac.in
An Autonomous Institute under Ministry of Education, Govt. of India.

M. Tech in Intelligent Mechanical Systems

Semester-I

Sl. No.	Course Code	Course Name	L	T	P	Credits
1	ME513	Computational Methods in Engineering	3	0	0	6
2	ME515	Introduction to Artificial Intelligence and Machine Learning	3	0	0	6
3	ME517	Smart Sensors	3	0	0	6
4	ME519	Intelligent Control Systems	3	0	0	6
5	ME5xx	Elective I	3	0	0	6
6	ME533	Computational Engineering Lab	0	0	3	3
7	ME535	Artificial Intelligence and Machine Learning Lab	0	0	3	3
	Total		**15**	**0**	**6**	**36**

Semester-II

Sl. No.	Course Code	Course Name	L	T	P	Credits
1	ME510	Cyber-Physical Security in Mechanical Systems	3	0	0	6
2	ME512	Additive and Hybrid Manufacturing Processes	3	0	0	6
3	ME516	Green Intelligent Systems	3	0	0	6
4	ME5xx	Elective II	3	0	0	6
5	ME536	Intelligent Systems Lab	0	0	3	3
6	ME534	Seminar	0	0	2	2
	Total		**12**	**0**	**5**	**29**

Semester-III

Sl. No.	Course Code	Course Name	L	T	P	Credits
1	ME633	M. Tech Dissertation Phase I	0	0	24	24
	Total		**0**	**0**	**24**	**24**

Semester-IV

Sl. No.	Course Code	Course Name	L	T	P	Credits
1	ME634	M. Tech Dissertation Phase II	0	0	24	24
	Total		**0**	**0**	**24**	**24**

Total credits: 113

List of Departmental Electives

Sl. No.	Course Code	Course Name	L	T	P	Credits	Category
1	ME563	Finite Element Method	3	0	0	6	**Department Elective I**
2	ME565	Advanced Mechanics of Solids	3	0	0	6	
3	ME567	Condition Monitoring Techniques	3	0	0	6	
4	ME569	Advanced Heat Transfer	3	0	0	6	
5	ME571	Engineering Design with Advanced Materials	3	0	0	6	
6	ME573	Internet of Things and Smart Manufacturing	3	0	0	6	
7	ME575	Manufacturing Automation	3	0	0	6	
8	ME577	Viscous Fluid Flows	3	0	0	6	
9	ME579	MEMS and Microsystems	3	0	0	6	
10	ME581	Machine Vision and Image Processing	3	0	0	6	
11	ME583	Optimization in Engineering Systems	3	0	0	6	
12	ME585	Thermal design and Hotspot Management	3	0	0	6	
13	ME587	Ethics of AI	3	0	0	6	
14	ME580	Smart Materials and Structures	3	0	0	6	**Department Elective II**
15	ME582	Intelligent Refrigeration and Air Conditioning Systems	3	0	0	6	
16	ME584	Non-Linear Finite Element Methods	3	0	0	6	
17	ME586	Turbulent flows	3	0	0	6	
18	ME588	Bio-inspired Designs	3	0	0	6	
19	ME590	Advanced Mechanical Vibrations	3	0	0	6	
20	ME592	Human–Machine Interaction	3	0	0	6	
21	ME594	Instrumentation and Measurement Systems	3	0	0	6	
22	ME596	Mechatronics System Design	3	0	0	6	
23	ME598	Computational Fluid Dynamics	3	0	0	6	
24	ME600	Rotor Dynamics	3	0	0	6	
25	ME602	Scientific Machine Learning	3	0	0	6	

Syllabus of Core Courses

ME513 **3-0-0-6**

Computational Methods in Engineering

Course Outcomes:

CO1	Solve engineering problems with accuracy and efficiency using various computational methods.
CO2	Apply numerical techniques for solving linear, nonlinear, ODE, and PDE-based engineering models.
CO3	Develop computational models using MATLAB/Python for mechanical and intelligent systems.
CO4	Apply optimization and data-driven techniques for engineering design and prediction.
CO5	Conduct simulation-based projects to solve real-world mechanical problems.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	-	3
CO2	3	-	3
CO3	3	-	3
CO4	3	-	3
CO5	3	-	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Numerical Methods: Error analysis, stability, convergence; Solutions of linear and nonlinear algebraic equations; Modelling and simulation concepts.

Numerical Linear Algebra: Solution of linear systems: Gauss elimination, LU decomposition; Iterative methods: Jacobi, Gauss–Seidel, SOR; Eigenvalue problems: Power method, QR method; Applications in robotics, control systems, and structural analysis

Differential Equations in Engineering: Initial value problems: Euler, RK family, multi-step methods; Boundary value problems: Shooting, Finite difference; PDEs: Heat, wave, Laplace equations.

Optimization Techniques: Unconstrained optimization: Gradient descent, Newton method; Constrained optimization: Lagrange multipliers, KKT conditions; Engineering optimization: design optimization, parameter tuning; Evolutionary algorithms (GA, PSO) for intelligent systems

Applications in Intelligent Mechanical Systems: Computational modelling of mechatronic systems; Digital twins & real-time simulation; Case studies: robotics, thermal systems, structural health monitoring. **Text Books:**

1. Numerical Methods for Engineers, Chapra, S.C., and Canale, R.P., McGraw-Hill Publishing Co., 8th Edition, 2021.
2. Numerical Analysis for Engineers: Methods and Applications, Ayyub, B.M., and McCuen R.H., Routledge, 3rd Edition, 2026.

Reference Books:

1. Applied Numerical Analysis Using MATLAB, Fausett, L.V., Pearson Education.
2. Mathematical Methods in the Physical Sciences, Boas, M.L., Wiley.

Online Resources:

1. https://nptel.ac.in/courses/103106118

ME515 **3-0-0-6**

Introduction to Artificial Intelligence and Machine Learning

Course Outcomes

CO1	Analyze role of AI & ML in intelligent mechanical systems.
CO2	Apply mathematical and statistical foundations to develop ML models.
CO3	Implement supervised and unsupervised ML algorithms using Python.
CO4	Design and implement neural networks for intelligent mechanical applications.
CO5	Integrate AI/ML solutions in robotics, manufacturing, and predictive maintenance.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	-	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Foundations of AI: History and evolution of AI; AI in mechanical engineering applications; Problemsearch); Intelligent agents and decision-solving and search techniques (uninformed & informed -making

Machine Learning Basics: Linear algebra for ML: vectors, matrices, eigenvalues; Probability & statistics: distributions, Bayes rule; Optimization: gradient descent, stochastic gradient descent; Loss functions, overfitting, regularization; Bias–variance tradeoff

Supervised and Unsupervised Learning: Classification and Regression; Algorithms: Linear & Polynomial Regression, Logistic Regression, K-Nearest Neighbors, Decision Trees, Random Forest, Support Vector Machines; Clustering: Kclustering, DBSCAN; Dimensionality reduction: PCA, t-SNE; Anomaly detection -means, Hierarchical (applications in machine faults).

Neural Networks and Deep Learning: Perceptron and multilayer neural networks; Backpropagation algorithm; Introduction to Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs).

AI & ML for Intelligent Mechanical Systems: AI in robotics and autonomous systems; Predictive maintenance using ML; Digital twins; Industry 4.0 and smart manufacturing.

Text Books:

1. Artificial Intelligence: A Modern Approach, Russell, S., and Norvig, P., 4th Edition, 2020.
2. Machine Learnin, Animated, Liu, M, CRC Press, 1st Edition, 2024.

Reference Books:

1. Artificial Intelligence Basics: A Non-Technical Introduction, Tom Taulli, 1st Edition, 2019.
2. Pattern Recognition and Machine Learning, Bishop, C.M., 1st Edition, 2006.

Online Resources:

1. https://nptel.ac.in/courses/106105079
2. https://nptel.ac.in/courses/108103192

ME517 **3-0-0-6**

Smart Sensors

Course Outcomes:

CO1	Analyze the principles, characteristics, and classifications of smart sensors and actuators.
CO2	Analyze sensor signals, perform signal conditioning, and interface sensors with embedded systems.
CO3	Evaluate smart actuator technologies and their application in intelligent mechanical systems.
CO4	Apply MEMS and IoT concepts to design modern sensing systems.
CO5	Integrate and implement intelligent sensor–actuator systems using AI/ML for real-world applications.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	-	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Smart Sensors: Classification of sensors: displacement, force, strain, piezoelectric, thermal, proximity, flow, chemical sensors; Static & dynamic bandwidth; Smart sensor architecture; Selfcharacteristics: accuracy, repeatability, -calibration, selfresolution, -diagnosis, and sensitivity, intelligent features.

Sensor Interfacing and Signal Conditioning: Analog and digital signal conditioning; Wheatstone bridge, instrumentation amplifiers, filters (active/passive);

ADC/DAC, sampling, anti-aliasing; Communication protocols: I2C, SPI, UART, CAN, LIN; Embedded data acquisition using microcontrollers.

Smart Actuators and Actuation Technologies: Types of actuators: electromagnetic, hydraulic, pneumatic; Smart materials: shape memory alloys (SMA), piezoelectric actuators, magnetostrictive actuatorsmicro-positioning; Actuator modeling and characteristics: response time, torque, , electroactive polymers; Micro-actuators and force production, hysteresis.

MEMS and IoT-Enabled Sensing Systems: MEMS sensor principles: accelerometers, gyroscopes, pressure sensors, micro-thermal sensors; Fabrication basics: lithography, etching, thin-film deposition; Sensor miniaturization and integration; IoT and wireless sensor networks (WSN).

Applications in Intelligent Mechanical Systems: Robotics: proprioceptive and exteroceptive sensors; Autonomous systems: LIDAR, ultrasonic, inertial navigation sensors; Automotive applications: pressure, oxygen, knock, ABS wheel sensors; Industrial automation: proximity, force, flow and smart actuators

Text Books:

1. Smart Sensors: Design, Challenges, and Applications, Shukla, M.K., Malik, P.K., Jain, A., Mishra, N.K., CRC Press, 1st Edition, 2025.

Reference Books:

1. Sensors and Actuators: Engineering System Instrumentation, Raghuwanshi, M., and Raghuwanshi, R., 1st Edition, 2013.
2. Sensor Technology Handbook, Wilson, J.S., 1st Edition, 2005.

Online Resources: https://onlinecourses.nptel.ac.in/noc25_ee31/preview

3-0-0-6

ME519

Intelligent Control Systems

Course Outcomes:

CO1	Analyze the architecture of intelligent control systems.

CO2	Design and analyze fuzzy logic and neural network controllers for dynamic mechanical systems.
CO3	Apply adaptive and robust control strategies to uncertain and nonlinear systems.
CO4	Utilize evolutionary and optimization algorithms for intelligent controller design.
CO5	Integrate intelligent control techniques in robotics, autonomous systems, and intelligent mechanical systems.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Intelligent Control: Review of classical control theory; Architecture of intelligent controllers; Intelligent mechanical systems: examples and applications; Review of linear and nonlinear systems; state-space representation.

Fuzzy Logic Control: Fuzzy sets and membership functions; Linguistic variables and rulecontrollers for mechanical systems-based systems; Fuzzy inference systems (Mamdani, Sugeno); Design of fuzzy ; Adaptive fuzzy controllers

Adaptive and Robust Control: Parameter adaptation and model reference adaptive control (MRAC);Robustness considerations (disturbances + uncertainties). Self-tuning regulators; Introduction to slid ing mode control;

Evolutionary and Optimization-Based Control: Genetic algorithms (GA) for controller tuning; Particle Swarm Optimization (PSO); Model Predictive Control (MPC) – fundamentals; Reinforcement Learning (RL) basics for control; Optimization of controller parameters.

Intelligent Control Applications: Intelligent control of robots, autonomous vehicles, drones; Smart actuators and sensors in intelligent control loops; Digital twin and real-time adaptive control.

Text Books:

1. Intelligent Control Systems: Theory and Applications, Passino, K.M., and Yurkovich, S.
2. Adaptive Control, Astrom, K, J., Wittenmark, B.

Reference Books:

1. Fuzzy Control, Passino, K.M., and Yurkovich, S., 1st Edition, 1998.
2. Neural Networks and Fuzzy Logic Systems, Mendel, J.M., 1st Edition, 1995.

Online Resources:

1. https://nptel.ac.in/courses/108104049 2. https://nptel.ac.in/courses/127105006

0-0-3-3

ME533

Computational Engineering Lab

Sl. No.	List of Experiments
1	MATLAB/Python for solving linear algebra problems
2	ODE/PDE simulation of mechanical systems
3	Computational modelling of robotic/manipulator dynamics
4	Sensor data analytics
5.	Simulation of control algorithms (PID, state feedback) for electromechanical systems
6.	Finite element–based simulation of solid and structural mechanics
7.	Numerical solution of nonlinear algebraic systems arising in engineering models

0-0-3-3

ME535

Artificial Intelligence and Machine Learning Lab

Sl. No.	List of Experiments
1	Python basics for AI/ML: data types, Numpy, Pandas, Matplotlib
2	Implement search algorithms: BFS, DFS, A* with heuristic
3	Data preprocessing: normalization, encoding, missing data handling
4	Implement Linear Regression and evaluate performance
5	Decision Trees and Random Forests on mechanical datasets
6	Implement K-Means clustering and visualize clusters
7	Implement a simple neural network (MLP) using Keras/PyTorch
8	Introduction to CNNs for visual inspection tasks

3-0-0-6

ME 510

Cyber-Physical Security in Mechanical Systems

Course Outcomes:

CO1	Analyze the architecture and fundamental components of Cyber-Physical Systems.
CO2	Develop mathematical models for continuous physical dynamics and discrete computational logic (Hybrid Systems).
CO3	Implement embedded systems for real-time CPS applications.
CO4	Design and implement sensing, actuation, and communication protocols for intelligent machines.
CO5	Analyze CPS stability, performance, and security against cyber-attacks.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to CPS Architecture: Definition and characteristics of CPS; The 5C architecture: Connection, Conversion, Cyber, Cognition, and Configuration; Difference between Embedded Systems, IoT, and CPS.

Modeling Physical and Cyber Components: Physical Modeling: Differential equations, State-space models of mechanical systems; Cyber Modeling: Finite State

Machines (FSM), Extended State Machines; Hybrid Systems: Modeling systems with both continuous and discrete behaviors using Hybrid Automata.

Embedded Computing and Real-Time Systems: Embedded processors and CPS hardware platforms; Real-time operating systems (RTOS) concepts; Task scheduling and timing constraints; Sensing, actuation, and I/O handling; Hardware-in-the-loop (HIL) and software-in-the-loop (SIL); Fault tolerance and reliability.

Communication and Networking: Networked Control Systems (NCS);

Communication protocols: MQTT, CoAP, CAN Bus (for automotive), and Industrial Ethernet; Impact of network delay, packet loss, and jitter on mechanical performance.

Security and Reliability: Cyber-physical security: Vulnerabilities in mechanical hardware; Attack models: Denial of Service (DoS), False Data

Injection (FDI); Safety-critical design and Fault-tolerant control.

Text Books:

1. Introduction to Embedded Systems: A Cyber-Physical Systems Approach by Edward A. Lee and Sanjit A. Seshia.

Reference Books:

1. Cyber-Physical Systems Security, Rawat, D.B., Bajracharya, C., and Yan, G., 1st Edition, 2019.
2. Security and Privacy in Cyber-Physical Systems, Humayed, A., Lin, J., Li, F., and Luo, B., 1st Edition, 2017.

Online Resources:

1. http://nptel.ac.in/courses/106105241

3-0-0-6

ME512 Additive and Hybrid Manufacturing Processes

Course Outcomes:

CO1	Demonstrate in-depth knowledge of additive manufacturing (AM) processes, materials, and applications.
CO2	Analyze various AM processes and their suitability for mechanical applications.
CO3	Categorize the materials involved in additive manufacturing.

CO4	Explain hybrid manufacturing processes and evaluate their advantages for precision applications.
CO5	Apply DfAM principles, topology optimization, and design automation for AM.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	1	3
CO3	3	-	3
CO4	3	-	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Additive Manufacturing: Evolution of manufacturing

technologies; Principles of additive manufacturing; → Slicing → Printing → Post-processing. AM workflow: CAD → STL

Additive Manufacturing Processes: Vat photo-polymerization (SLA, DLP); Material

extrusion (FDM); Powder bed fuBinder jetting and sheet lamination.sion (SLS, SLM, EBM); Directed energy deposition;

Materials for Additive Manufacturing: Polymers, metals, ceramics, composites;

Material properties and processing challenges; Microstructure and mechanical performance; Recycling and sustainability in AM.

Hybrid Manufacturing Processes: Additive + subtractive systems (laser metal deposition + CNC machining); Metal AM with post machining for accuracy; Ultrasonic AM + machining; Friction stir additive manufacturing; Applications in repair, remanufacturing, tooling; Hybrid robotics-based systems.

Applications: AM in mechanical industries, biomedical implants, aerospace/defense, robotics; Smart materials & functionally graded materials through AM; Large-scale AM (WAAM, concrete printing).

Text Books:

1. Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson, I., Rosen, D., & Stucker, B.
2. Hybrid Manufacturing: Emerging Processes, Materials, and Applications, Debroy, T., and Bag, S.

Reference Books:

1. Additive and Subtractive Manufacturing, Liou, F.W., 1st Edition, 2017.
2. Additive Manufacturing Technologies, Gibson, I., Rosen, D.W., and Stucker, B., 3rd Edition, 2021.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc22_me130/preview

Credits 3-0-0-6

ME 516

Green Intelligent Systems

Course Outcomes:

CO1	Evaluate the environmental impact of mechanical systems using Life Cycle Assessment (LCA) and digital twin simulations.
CO2	Design intelligent control strategies for energy-efficient operations in industrial and robotic systems.
CO3	Apply Generative Design and AI-driven optimization to minimize material usage and maximize recyclability.
CO4	Implement Green-IoT (G-IoT) frameworks for real-time monitoring of resource consumption and carbon emissions.
CO5	Develop strategies for Circular Economy in mechanical systems, focusing on remanufacturing and end-of-life intelligence.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	1	3
CO3	3	1	3
CO4	3	1	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Foundations of Eco-Intelligence: The transition from Lean to Green to Eco-

Intelligent Manufacturing; Key Sustainability Indicators: Footprint, and Embodied Energy; Introduction to Sustainable Intelligence (SI).Carbon Footprint, Water

Life Cycle Engineering and Eco-Design Methods: Life Cycle Assessment (LCA): cradle-to-grave approach; Environmental impact metrics (carbon footprint, energy intensity); Design for environment (DfE), design for sustainability (DfS); Circular economy and resource efficiency; Materials selection for eco-intelligent systems.

Energy-Aware Intelligent Systems: Machine Learning for Predictive Energy Management; Intelligent HVAC and Thermal Management in Industrial Systems; Optimization of Power Consumption in Robotics and Autonomous Mobile Robots (AMRs); Integration of renewable energy sources with intelligent mechanical grids.

Real-time Eco-Monitoring & G-IoT: Deploying low-power sensors for environmental auditing; Digital Twins for Sustainability: Real-time simulation of wear-and-tear to extend product life; Edge Computing vs. Cloud Computing: The carbon trade-off of AI computations.

Circular Economy & Remanufacturing Intelligence: Predictive Maintenance (PdM) as a tool for product life extension; Blockchain for tracking material provenance and "Product Passports."AI-based sorting and disassembly robots for waste management; Ethical considerations in the trade-off between technological performance and environmental health.

Text Books:

1. Environmentally Conscious Manufacturing, Gungor, A., Gupta, S. M. **Reference Books:**

1. Sustainable Intelligent Systems, Abraham, A., and Corchado, J.M., 1st Edition, 2018.
2. Artificial Intelligence for Sustainable Development, Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., Felländer, A., Langhans, S.D., Tegmark, M., and Fuso Nerini, F., 1st Edition, 2020.

Online Resources: https://nptel.ac.in/courses/105105157

Credits 0-0-3-3

ME536

Intelligent Systems Lab

Sl. No.	Experiments (Intelligent Systems Lab)
1	Python/Matlab refresher for SciML (NumPy, PyTorch/TensorFlow, SciPy)
2	SINDy for identifying equations of motion of a robotic arm or vibration system
3	Closed-loop control of electromechanical systems
4	IoT-based mechatronic system monitoring

5 Gaussian Process surrogate model for structural or thermal problem
6. Neural ODE for mechanical dynamics
7. AI-based fault classification using vibration data
8. Create a digital model of the printed rotor and compare simulated vs. experimental behavior.
9. Real-time monitoring and predictive maintenance simulation using IoT-enabled sensors
10. Operator learning demo using DeepONet/FNO for a PDE

Syllabus of Department Elective I Courses

Credits 3-0-0-6

ME563

Finite Element Method

Course Outcomes:

CO1	Apply the mathematical foundations, element formulations, and solution strategies of FEM
CO2	Formulate and solve 1D and 2D engineering problems using FEM
CO3	Analyze 3D mechanical systems using FEM techniques.
CO4	Apply FEM for heat transfer, thermal stresses, and multiphysics problems in mechanical systems.
CO5	Use modern FEM tools to model, simulate, and analyze intelligent mechanical systems and develop engineering solutions.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	-	3
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Finite Element Method: Steps in FEM: discretization, element formulation, assembly, solution; Types of elements: 1D, 2D, 3D, higher-order elements; Boundary conditions (essential & natural); Weighted residual methods: collocation, Galerkin method.

One-Dimensional Finite Elements: Bar, truss, beam, and frame elements; Shape functions, interpolation & approximation; Stiffness matrix formulation; Assembly and boundary application; Axial loading, bending, torsion problems.

Twoaxisymmetric problems; Triangular and quadrilateral elements; Isoparametric **-Dimensional and Three-Dimensional Elements:** Plane stress, plane strain, and formulation; Numerical integration and Gauss quadrature.

FEM for Heat Transfer and Thermal–Structural Analysis: 1D & 2D heat conduction FEM; Transient heat transfer formulation; Thermal stresses and coupled thermo-mechanical problems; Applications in hotspot analysis, battery & electronics cooling.

FEM Software Applications: Introduction to commercial FEM tools: ANSYS, ABAQUS, COMSOL; Mesh generation techniques and mesh convergence; Adaptive meshing and error estimation; Multi-physics FEM (thermal-fluid, electro-mechanical, piezoelectric).

Text Books:

1. The Finite Element Method: Its Basis and Fundamentals, Zienkiewicz, O.C.
2. Concepts and Applications of Finite Element Analysis, Cook, R.D.

Reference Books:

1. A First Course in the Finite Element Method, Logan, D.L., 6th Edition, 2016.
2. Concepts and Applications of Finite Element Analysis, Cook, R.D., Malkus, D.S., Plesha, M.E., and Witt, R.J., 4th Edition, 2001

Online Resources: https://onlinecourses.nptel.ac.in/noc22_me43/preview

3-0-0-6

ME565

Advanced Mechanics of Solids

Course Outcomes:

CO1	Analyze advanced stress, strain, and constitutive relations in 3D mechanical systems.
CO2	Apply elasticity theory to solve complex engineering boundary value problems.
CO3	Use energy and variational methods for modelling and approximate solutions in solid mechanics.
CO4	Analyse plasticity, viscoelasticity, and creep behaviour for advanced and smart materials.
CO5	Evaluate fracture and fatigue behaviour and apply advanced mechanics concepts in intelligent mechanical systems.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	-	3
CO3	3	-	3
CO4	3	2	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Stress and Strain: 3D stress and strain tensors; Principal stresses, Mohr's circle in 3D; Transformation of stress/strain; Generalized Hooke's law; Elastic constants and anisotropy; Energy functions and stability criteria.

Elasticity Theory: Governing equations of elasticity; Compatibility conditions; Boundary value problems; Plane stress and plane strain; Torsion of prismatic bars.

Energy Methods: Total potential energy; Virtual work and virtual displacement; Rayleigh–Ritz method; Galerkin's method; Weighted residual methods

Plasticity, Viscoelasticity & Creep: Yield criteria: von Mises, Tresca; Flow rules

and hardening laws; Elastoplastic stressMaxwell, Voigt, Standard Linear Solid; Creep laws and time–strain relations; Viscoelasticity models: -dependent deformation.

Fracture Mechanics & Fatigue: Stress concentration and crack-tip fields; Modes of fracture: Mode I, II, III; Griffith theory, energy release rate, stress intensity factor; Paris law for fatigue crack growth; Dynamic fracture.

Text Books:

1. Advanced Mechanics of Materials, Boresi, A.P., Schmidt, R.J., and Sidebottom, O.M., 6th Edition, 2003.
2. Theory of Elasticity, Timoshenko, S.P., and Goodier, J.N., 3rd Edition, 1970.

Reference Books:

1. Elasticity, Sadd, M.H., 3rd Edition, 2014.
2. Advanced Strength and Applied Elasticity, Ugural, A.C., and Fenster, S.K., 5th Edition, 2012.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc22_me43/preview

3-0-0-6

ME567

Condition Monitoring Techniques

Course Outcomes:

CO1	Analyze principles of condition monitoring, failure modes, and predictive maintenance.
CO2	Perform vibration-based fault diagnosis of rotating and mechanical systems.
CO3	Apply acoustic, ultrasonic, thermal, lubrication, and electrical CM methods for detecting faults.
CO4	Use signal processing tools for feature extraction and fault characterization.
CO5	Implement intelligent diagnostic and prognostic techniques using AI/ML and digital twins.

Course Articulation Matrix:

COs	POs		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	-	3
CO3	3	-	3
CO4	3	2	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Condition Monitoring: Need for CM & Predictive Maintenance

(centered maintenance (RCM); Types: Periodic, continuous, online, remote CM.PdM); Failure modes, mechanisms, and degradation behaviour; Reliability

Vibration Monitoring: Vibration signatures of common faults: unbalance, misalignment, looseness, bearing faults, gear faults; Time-domain, frequency-domain, and time–frequency analyses; FFT, PSD, cepstrum, envelope demodulation; Order analysis for rotating machinery.

Acoustic, Ultrasonic & Noise Monitoring: Acoustic emission fundamentals; Ultrasonic leak detection; High-frequency stress wave analysis; Noise and sound signature analysis.

Thermal, Lubrication & Electrical Monitoring: IR thermography principles and hotspot detection; Thermocouples, MEMS temperature sensors; Lubricant analysis: wear debris, viscosity, chemical composition;

Intelligent Monitoring Systems: IoT-enabled sensors and wireless monitoring; Machine learning and AI in fault diagnosis; Digital twins for predictive maintenance

Text Books:

1. Condition Monitoring and Control for Intelligent Manufacturing, Wang, L., and Gao, R.

Reference Books:

1. Practical Machinery Vibration Analysis and Predictive Maintenance, Mobley, R.K., 2nd Edition, 2001.
2. Mechanical Condition Monitoring, Harris, C.M., and Piersol, A.G., 2nd Edition, 2002.

Online Resources:

1. https://nptel.ac.in/courses/112105232

3-0-0-6

ME569

Advanced Heat Transfer

Course Outcomes:

CO1	Model advanced conduction, convection, and radiation heat transfer mechanisms.
CO2	Solve complex thermal problems using numerical and computational methods.
CO3	Analyze multiphase and phase-change heat transfer relevant to heat exchanger systems.
CO4	Evaluate microscale and nanoscale heat transfer phenomena in modern intelligent mechanical systems.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	1	3
CO3	3	-	3
CO4	3	-	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Advanced Conduction Heat Transfer: General conduction equation in Cartesian, cylindrical, spherical coordinates; Use of Green's functions, Bessel functions for conduction; Transient conduction: lumped, semi-infinite, finite domains; Heisler charts revisited, Duhamel's theorem; Multidimensional conduction in composite structures; Heat spreading & thermal resistance in intelligent mechanical systems.

Advanced Convection Heat Transfer: Exact solutions of Navier–Stokes for simple geometries; Boundary layer theory, similarity solutions; Turbulent convection, turbulence modelling basics (k–ε, LES overview); Forced and natural

convection at high Rayleigh/Reynolds numbers; Convective heat transfer in confined and electronics-cooling flows; Jet impingement cooling & microchannel cooling.

Radiation Heat Transfer: Radiation exchange between non-grey surfaces; Configuration factors, radiation shields, view factor algebra; Radiative heat transfer in participating media; Gas radiation models: Hottel charts, weighted-sum-of-grey-gases (WSGG); Radiation in high-temperature and combustion systems.

Heat Exchangers & Applications: Design and analysis of heat exchangers (LMTD, NTU methods); Compact heat exchangers and microchannel systems; Intelligent monitoring and optimization of heat exchangers using IoT and AI.

Microscale & Nanoscale Heat Transfer: Ballistic vs diffusive heat conduction; Phonon transport & Boltzmann transport equation; Thermal interface materials (TIMs); Nanofluids – theory & applications; Microfabricated heat exchangers; Heat transfer in MEMS, robotic sensors, microactuators; Thermoelectric cooling & Peltier devices

Text Books:

1. Convection Heat Transfer, Bejan, A.
2. Radiative Heat Transfer, Modest, M., F.

Reference Books:

1. Heat Transfer, Incropera, F.P., DeWitt, D.P., Bergman, T.L., and Lavine, A.S., 7th Edition, 2011.
2. Advanced Heat and Mass Transfer, Kaviany, M., 2nd Edition, 2014.

Online Resources: https://onlinecourses.nptel.ac.in/noc25_ch88/preview

3-0-0-6

ME571

Engineering Design with Advanced Materials

Course Outcomes:

CO1	Analyze classifications, properties, and design considerations of advanced engineering materials.
CO2	Apply design principles for advanced structural materials, composites, and ceramics.
CO3	Design and evaluate smart and adaptive material systems for intelligent mechanical applications.
CO4	Analyse architected and additive-manufactured materials using computational tools.
CO5	Perform material modelling, optimization, and data-driven selection for engineering design.

Course Articulation Matrix:

COs	POs		
	PO1	PO2	PO3
CO1	2	-	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Advanced Materials: Classification of advanced materials: structural, functional, smart, metamaterials; Material indices, Ashby charts, performance-based material selection; Property–process–performance relationships; Lightweighting and design for high-performance systems.

Advanced Structural Materials: High-strength alloys: titanium, aluminium-lithium, maraging steels; Superalloys for extreme environments; Design with ceramics and glass–ceramics; High-temperature materials and thermal barrier coatings; Mechanical behaviour: creep, fatigue, fracture, impact resistance

Smart and Functional Materials: Piezoelectric, magnetostrictive, shape-memory alloys (SMA), electroactive polymers; Constitutive modelling & actuation principles; Design of adaptive/smart structures; Vibration control, morphing structures, soft robotics applications.

Additive Materials, Architected Materials & Metamaterials: Lattice materials, auxetics, graded materials; Mechanical & thermal behaviour of architected materials; AM-enabled materials: topology-optimized microstructures, cellular metals; Design for multi-functional performance (thermal + structural + damping).

Material Modelling, Simulation & Data-Driven Design: Multiscale material modelling: microstructure–property relations; FEM for composite and smart material structures; Material optimization: topology, size, and material distribution; Machine learning for material prediction, surrogate models; Material databases (CES Selector, JMATPRO).

Text Books:

1. Materials Selection in Mechanical Design, Ashby, M., F. **Reference Books:**

1. Advanced Materials and Design for Engineering Applications, Banerjee, M.K., 1st Edition, 2014.
2. Introduction to Materials Science for Engineers, Shackelford, J.F., 8th Edition, 2015.

Online Resources: https://onlinecourses.nptel.ac.in/noc20_me08/preview

3-0-0-6

ME573

Internet of Things and Smart Manufacturing

Course Outcomes:

CO1	Analyze IoT concepts, architectures, and Industry 4.0 principles in manufacturing.
CO2	Design IoT-based sensing and data acquisition systems for intelligent mechanical applications.
CO3	Develop IoT-enabled solutions for predictive maintenance and condition monitoring.
CO4	Develop secure, intelligent, and sustainable IoT solutions for smart manufacturing.
CO5	Analyze smart manufacturing systems using IoT, analytics, and digital twins.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	1	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to IoT and Industry 4.0: Evolution from automation to Industry 4.0; IoT definition, characteristics, and enabling technologies; Cyber-Physical Systems (CPS) in manufacturing; Smart factory concepts and reference architectures (RAMI 4.0).

IoT Architecture and Hardware Systems: IoT architecture: perception, network,

middleware, application layers; Sensors and actuators for manufacturing systems; Embedded platforms: Arduino, ESP32, Raspberry Pi; Industrial IoT (IIoT) hardware and PLC integration; Edge computing vs cloud computing.

IoT Applications in Mechanical Systems: Predictive maintenance using IoT; Condition monitoring of machines; Energy management in manufacturing systems.

Smart Manufacturing Systems: Smart sensors and smart machines; IoT-enabled CNC, robotics, and additive manufacturing; Flexible and reconfigurable manufacturing systems; Manufacturing Execution Systems (MES) and ERP integration; Digital thread and smart supply chains; Vulnerability management in smart manufacturing.

Data Analytics, AI & Digital Twins for Manufacturing: Data analytics for manufacturing intelligence; Predictive maintenance and condition monitoring using IoT data; Machine learning for quality prediction and process optimization; Digital twins for machines and manufacturing systems.

Text Books:

1. Internet of Things: A Hands-On Approach, Bahga, A., and Madisetti, V.

Reference Books:

1. Industrial Internet of Things, Gilchrist, A., 1st Edition, 2016.
2. Cyber-Physical Systems: Foundations, Principles and Applications, Rajkumar, R., Lee, I., Sha, L., and Stankovic, J., 1st Edition, 2017.

Online Resources: https://nptel.ac.in/courses/106105195

3-0-0-6

ME575

Manufacturing Automation

Course Outcomes:

CO1	Analyze the architecture of manufacturing automation systems.
CO2	Design automated production lines and material handling systems
CO3	Apply robotics, PLCs, sensors, and actuators for manufacturing automation.

CO4	Evaluate flexible, computer-integrated, and smart manufacturing systems.
CO5	Design intelligent and sustainable automated manufacturing solutions.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Manufacturing Automation: Evolution of manufacturing systems; Types of automation: fixed, programmable, flexible; Automation strategies and justification; Automation pyramid and CIM architecture.

Automated Production Systems & Transfer Lines: Components of automated productionrate, availability, and reliability; Line balancing and bottleneck analysis. systems; Transfer lines and automated flow lines; Analysis of production

Robotics and Automated Material Handling: Industrial robots: types, configurations, and applications; Robot kinematics and dynamics basics; Automated Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs); Material handling systems: conveyors, automated storage and retrieval systems (AS/RS).

CNC and Flexible Manufacturing Systems: CNC machine tools: structure, programming, and operation; ComputerFlexible Manufacturing Systems (FMS): components, layout, and scheduling.-Aided Manufacturing (CAM) integration;

Advanced & Intelligent Automation: AI and ML in manufacturing automation; Predictive maintenance and condition monitoring; Vision systems and intelligent inspection; Human–robot collaboration (cobots) **Text Books:**

1. Manufacturing Automation: Metal Cutting Mechanics, Machine Tool Vibrations, and CNC Design, Altintas, Y. **Reference Books:**

1. Automation, Production Systems, and Computer-Integrated Manufacturing, Groover, M.P., 4th Edition, 2015.
2. Robotics and Automation Handbook**,** Niku, S.B., 1st Edition, 2001. **Online Resources:**

1. https://onlinecourses.nptel.ac.in/noc22_me50/preview

3-0-0-6

ME577

Viscous Fluid Flows

Course Outcomes:

CO1	Derive and interpret governing equations for viscous fluid flows.
CO2	Solve laminar flow problems using analytical methods.
CO3	Apply boundary layer theory to practical engineering problems
CO4	Evaluate low-Reynolds-number and lubrication flows for micro/precision systems.
CO5	Apply viscous flow concepts to lubrication, microfluidics, and manufacturing systems.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	1	3
CO3	3	-	3
CO4	3	2	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Viscous Flows: Continuum hypothesis; kinematics of fluids; Stress tensor; Newtonian and non-Newtonian fluids; Conservation laws: mass,

momentum, energy; NavierNon-dimensionalization; Reynolds, Mach, Prandtl numbers; Bound–

Stokes equations (incompressible/compressible); ary and initial conditions; well-posedness.

Laminar Flow Analysis: Exact solutions of Navier–Stokes equations for simple

geometries; Hagenparallel plates; Flow in annuli and between rotating cylinders. –Poiseuille flow in pipes; Couette and Poiseuille flows between

Boundary Layer Theory: Boundary-layer approximations; scaling analysis; Laminar boundary layers over flat plates; Similarity solutions (Blasius); Momentummethods (von Kármán–Pohlhausen); Flow separation and control concepts. -integral

Low-Reynolds-Number & Creeping Flows: Stokes flow assumptions and

lmotion in viscous fluids.inearization; Flow past spheres and cylinders; drag laws; Oseen correction; Particle

Applications of Viscous Flows: Lubrication theory and thin film flows; Microfluidics and MEMS applications; Heat transfer in viscous flows

Text Books:

1. Viscous Fluid Flow, White, F., M.

Reference Books:

1. Boundary-Layer Theory, Schlichting, H., and Gersten, K., 8th Edition, 2017.
2. Advanced Engineering Fluid Mechanics, Kundu, P.K., Cohen, I.M., and Dowling, D.R., 6th Edition, 2016.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc23_me57/preview

3-0-0-6

ME579

MEMS and Microsystems

Course Outcomes:

CO1	Analyze fundamentals, materials, and scaling laws governing MEMS and microsystems.
CO2	Explain and apply microfabrication processes for MEMS device realization.
CO3	Design and model MEMS sensors and actuators for mechanical applications.
CO4	Integrate MEMS devices with electronics and explore advanced applications.
CO5	Evaluate reliability, packaging, and integration issues in practical MEMS systems.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to MEMS and Microsystems: Evolution and scope of MEMS and microsystems; Scaling laws; surface-to-volume effects; MEMS materials: silicon, polymers, metals, ceramics; Transduction mechanisms: mechanical, electrical, thermal, optical.

Microfabrication Technologies: Cleanroom concepts and safety; Bulk and surface micromachining; Thin-film deposition: CVD, PVD, epitaxy; Lithography: photolithography, e-beam (overview); Etching: wet, dry (RIE, DRIE), release processes; Wafer bonding and packaging basics.

MEMS Devices and Design: MEMS sensors: pressure, acceleration, temperature,

chemical, biosensors; MEMS actuators: electrostatic, piezoelectric, thermal, magnetic; Microsystems design principles and modeling.

Microsystems Integration and Applications: Integration of MEMS with electronics (MEMS.ASICs, CMOS); Microfluidics and lab -on-chip systems; RF MEMS and optical

Modelling & Reliability: Lumped and distributed modelling of MEMS; FEM/CFD for MEMS (structural, thermal, electrostatic coupling); Failure modes and reliability (stiction, fatigue, wear); Packaging and testing.

Text Books:

1. Microsystem Design, Senturia, S., D.

Reference Books:

1. Fundamentals of Microfabrication and Nanotechnology, Madou, M.J., 3rd Edition, 2011.
2. MEMS and Microsystems: Design and Manufacture, Tai-Ran Hsu, 2nd Edition, 2008.

Online Resources:

1. https://nptel.ac.in/courses/117105082

3-0-0-6

ME581

Machine Vision and Image Processing

Course Outcomes:

CO1	Analyze fundamentals of machine vision systems and image acquisition.
CO2	Apply image processing techniques for enhancement, segmentation, and analysis.
CO3	Extract features and perform object recognition for mechanical applications.
CO4	Implement 3D vision and motion analysis for robotics and automation.
CO5	Develop intelligent vision systems using machine learning and deep learning.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Machine Vision Systems: Role of vision in intelligent mechanical systems; Human vision vs machine vision; Components of a machine vision system; Imaging sensors: CCD, CMOS; Optics and illumination techniques; Image formation and camera models.

Digital Image Fundamentals: Image representation and sampling; Gray-level transformations; Spatial resolution, histogram analysis; Noise models and image degradation; Image enhancement techniques; Color models and color image processing.

Image Processing Techniques: Spatial filtering: smoothing and sharpening; Frequency-domain processing (DFT, FFT); Edge detection: Sobel, Prewitt, Canny; Image segmentation: thresholding, region-based methods; Morphological operations; Binary image analysis.

Feature Extraction and Object Recognition: Feature descriptors: shape, texture, moments; Keypoint detection: Harris, SIFT, SURF (overview); Template matching; Pattern recognition techniques; Object classification methods.

3D Vision, Motion & Robotics Applications: Stereo vision and depth estimation; Camera calibration and pose estimation; Optical flow and motion analysis; Vision-based robot guidance and manipulation; Visual servoing concepts.

Text Books:

1. Machine Vision: Theory, Algorithms, Practicalities, Davies, E., R.

Reference Books:

1. Computer Vision: Algorithms and Applications, Szeliski, R., 2nd Edition, 2022.
2. Image Processing and Analysis, Sonka, M., Hlavac, V., and Boyle, R., 2nd Edition, 2008.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc23_ee39/preview

Credits 3-0-0-6

ME583

Optimization in Engineering Systems

Course Outcomes:

CO1	Model the optimization problems using mathematical formulation.

CO2	Apply linear, nonlinear, and constrained optimization techniques to engineering systems.
CO3	Use gradient-based methods for efficient optimization in dynamic and complex mechanical systems.
CO4	Implement evolutionary and metaheuristic algorithms for multi-objective and global optimization.
CO5	Integrate optimization techniques with intelligent mechanical systems, robotics, control, and Industry 4.0 applications.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	-	3
CO3	3	-	3
CO4	3	-	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Optimization: Types of optimization problems; Optimality conditions, convexity, feasibility; problems. Formulation of engineering optimization

Linear and Nonlinear Programming: Linear Programming (LP): Simplex method, duality; Integer Programming, Mixed-Integer Programming; Nonlinear Programming (NLP): unconstrained and constrained; Lagrange multipliers, KKT conditions; Quadratic programming.

Gradient-Based Optimization Methods: Steepest descent, Newton's method, quasi-Newton methods (DFP, BFGS); Conjugate gradient method; Line search strategies; Multi-variable optimization with constraints.

Evolutionary and Metaheuristic Optimization: Genetic algorithms (GA); Particle swarm optimization (PSO); Differential evolution (DE); Simulated annealing.

Advanced Optimization Tools & Applications: Surrogate modelling: RSM, Kriging, Gaussian Processes; Bayesian optimization; Machine learning-assisted optimization; Large-scale optimization using numerical solvers.

Text Books:

1. Optimization for Engineering Design: Algorithms and Examples, Deb, K.
2. Engineering Optimization: Theory and Practice, Rao, S, S.

Reference Books:

1. Practical Optimization, Gill, P.E., Murray, W., and Wright, M.H., 1st Edition, 1981.
2. Numerical Optimization, Nocedal, J., and Wright, S.J., 2nd Edition, 2006.

Online Resources:

1. https://nptel.ac.in/courses/108106478

Credits 3-0-0-6

ME585

Thermal design and Hotspot Management

Course Outcomes:

CO1	Analyze the fundamentals of thermal design and heat transfer for mechanical and electronic systems.
CO2	Analyze mechanisms and impact of hotspot formation in high-power devices and mechanical systems.
CO3	Evaluate advanced cooling techniques for hotspot suppression and system reliability.
CO4	Apply computational tools for thermal modelling, transient simulation, and design optimization.
CO5	Implement intelligent thermal management strategies using sensing, control, and AI-based prediction.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3

CO1	2	1	2
CO2	3	1	3
CO3	3	1	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Thermal Design: Review of conduction, convection & radiation; Extended surfaces / fins and fin optimization; Thermal resistances and heat spreading; Thermal material properties: metals, ceramics, polymers, composites

Hotspot Formation and Analysis: Sources of hotspots in mechanical and electronic systems; Thermal stresses and reliability issues; Analytical and numerical methods for hotspot detection.

Cooling Techniques for Hotspot Reduction: Air cooling: fans, blowers, heat sinks; Liquid cooling: cold plates, pump loops, microchannel cooling; Phase-change cooling: heat pipes, vapor chambers, twocondensation mechanisms; Emerging cooling technologies: nano-phase systems; Jet impingement cooling; Boiling and -fluids, PCM cooling, thermoelectric coolers.

Computational Thermal Analysis: Finite Difference, Finite Volume, and Finite Element thermal modelling; Heat sink and cold plate CFD analysis; Transient thermal simulation for hotspot prediction

Thermal Design for Intelligent Mechanical Systems: Thermal management in robotics, actuators, motors; High-performance mechatronic systems: servo drives, power electronics, sensors; Thermal challenges in additive manufacturing, welding & hybrid manufacturing; Thermal interfaces: TIMs, bonding, thermal vias; System-level thermal integration in autonomous vehicles and drones

Text Books:

1. Fundamentals of Heat and Mass Transfer, Incropera, F.P., & Dewitt, D.P
2. Thermal Management for Electronics, Lasance, C.,J.,M.

Reference Books:

1. Thermal Design and Thermal Behaviour of Electronic Systems, Bar-Cohen, A., and Kraus, A.D., 2nd Edition, 1999.
2. Hot Air Rises and Heat Sinks, Ellison, G.N., 1st Edition, 2002.

Online Resources:

1. https://nptel.ac.in/courses/112103313

3-0-0-6

ME587

Ethics of AI

Course Outcomes:

CO1	Analyze fundamental ethical theories and their application to autonomous mechanical systems.
CO2	Evaluate risks related to algorithmic bias and safety in automated manufacturing and robotics.
CO3	Apply frameworks for "Value Sensitive Design" (VSD) in the engineering lifecycle.
CO4	Navigate the legal and regulatory landscape (GDPR, AI Act) concerning intellectual property and liability in AI-driven engineering.
CO5	Formulate ethical solutions for human-robot collaboration and workforce displacement.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	2	2
CO2	3	2	3
CO3	3	2	3
CO4	3	2	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Foundations of AI Ethics: Introduction to Ethics: Deontology, Utilitarianism, and

Virtue Ethics; The evolution from "Asimov's Laws" to Modern AI Principles; Distinction between "narrow AI" in machines vs. "Artificial General Intelligence."

Safety and Liability in Autonomous Systems: The "Trolley Problem" in Autonomous Vehicles and UAVs; Machine Failures vs. Algorithmic Errors: Determining liability in accidents; Control Dilemmas: Human-in-the-loop, on-the- loop, and out-of-the-loop.

Fairness, Bias, and Accountability in AI Systems: algorithms; Algorithmic fairness and discrimination; Accountability and responsibility Sources of bias in data and in autonomous systems; Explainable AI (XAI) concepts; Transparency and trust in intelligent machines; Ethical implications of AI decision-making.

Human-Machine Interaction & Labor: The Impact of Industry 4.0/5.0 on employment in the mechanical sector; Psychological impact of Human-Robot Collaboration (Cobots); Transparency and Explainability (XAI) in complex mechanical diagnostics.

Governance, Law, and Sustainability: Global AI Regulations: EU AI Act, IEEE Standards, and India's NITI Aayog guidelines; Intellectual Property (IP) rights for AI-generated designs/patents; Environmental Ethics: The carbon footprint of training large models for fluid dynamics and structural optimization.

Text Books:

1. Ethics of Artificial Intelligence by S. Matthew Liao.

Reference Books:

1. Artificial Intelligence Ethics, Coeckelbergh, M., 1st Edition, 2020.
2. Ethics of Artificial Intelligence and Robotics, Lin, P., Abney, K., and Bekey, G.A., 1st Edition, 2017.

Online Resources:

1. https://nptel.ac.in/courses/106106472

Syllabus of Department Elective II Courses

3-0-0-6

ME580

Smart Materials and Structures

Course Outcomes:

CO1	Analyze principles, classifications, and applications of smart materials and structures.
CO2	Analyse constitutive behaviour and transduction mechanisms of smart materials.
CO3	Design smart structures integrating sensing, actuation, and control.
CO4	Model and simulate smart material systems using computational tools.
CO5	Evaluate advanced applications and emerging trends in intelligent smart structures.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	1	3
CO3	3	1	3
CO4	3	2	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Smart Materials and Structures: Definition and characteristics of smart materials; Classification: passive, active, adaptive, and intelligent materials; Smart structures: sensing–actuation–control paradigm; Scaling effects and multifunctionality.

Piezoelectric and Ferroelectric Materials: Piezoelectric effect and constitutive equations; Piezoelectric materials: PZT, PVDF; Sensors and actuators using piezoelectric materials; Energy harvesting applications; Modelling and FEM implementation of piezoelectric structures.

Shape Memory superelasticity; Constitutive behaviour of SMAs (NiTi); SMA actuators and design **Alloys and Smart Polymers:** Shape memory effect and considerations; Electroactive polymers (EAPs) and magnetorheological elastomers.

Magnetostrictive, ER & MR Materials: Magnetostriction and magnetostrictive materials; Electrorheological (ER) and magnetorheological (MR) fluids; Semivibration and shock control; Design of dampers and adaptive systems. -active

Modelling, Simulation & Emerging Trends: Coupled-field modelling of smart materials; FEM and multiphysics simulation (ANSYS/COMSOL); Reliability, fatigue, and durability of smart materials; Energy-efficient and sustainable smart systems; Emerging trends: self-healing materials, 4D printing, AI-enabled smart structures.

Text Books:

1. Smart Structures: Analysis and Design, Petrov, M., and Gupta, N.

Reference Books:

1. Piezoelectric Sensorics, Jaffe, B., Cook, W.R., and Jaffe, H., 1st Edition, 1971.
2. Introduction to Smart Materials, Schwartz, M., 1st Edition, 2002.

Online Resources:

1. https://nptel.ac.in/courses/112104173

3-0-0-6

ME582 Intelligent Refrigeration and Air Conditioning Systems

Course Outcomes:

CO1	Develop advanced understanding of refrigeration and air-conditioning systems and their performance characteristics.
CO2	Analyze intelligent sensing, control, and automation techniques for HVAC&R systems.
CO3	Apply modelling, simulation, and optimization techniques for energy-efficient HVAC systems.
CO4	Integrate AI/ML, IoT, and digital twins for smart refrigeration and air-conditioning applications.
CO5	Design intelligent RAC systems integrating sensors, automation, and smart algorithms.

Course Articulation Matrix:

COs	POs		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	1	3
CO3	3	1	3
CO4	3	2	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Advanced Refrigeration Systems: Review of vapor compression refrigeration systems; Advanced refrigeration cycles: multi-stage, cascade, economized cycles; Refrigerants: low-GWP refrigerants, natural refrigerants (CO_2, NH_3, hydrocarbons); System performance analysis and COP improvement.

Advanced Air Conditioning & HVAC Systems: Centralized and decentralized HVAC systems; Variable Refrigerant Flow (VRF/VRV) systems; Chillers, cooling towers, and district cooling; Psychrometric analysis for complex air-conditioning processes; Indoor air quality (IAQ) and thermal comfort standards.

Sensors, Instrumentation & Control in HVAC&R: Temperature, pressure, humidity, flow, and air-quality sensors; Actuators, valves, dampers, compressors, and drives; Control strategies: on-off, PID, adaptive and model-based control; Building Management Systems (BMS).

Intelligent & Smart HVAC Systems: IoT-enabled HVAC systems; Smart thermostats and distributed sensing; Predictive maintenance and condition monitoring; Demand-response and load management; Integration with smart grids and renewable energy sources.

Energy Efficiency, Modelling & Optimization: Energy analysis and benchmarking of HVAC systems; Exergy analysis of refrigeration and AC systems; HVAC system modelling (lumped and distributed models); Optimization techniques for system sizing and operation.

Text Books:

1. Advanced Refrigeration and Air Conditioning Systems, Hafiz, A.

Reference Books:

1. Refrigeration and Air Conditioning Technology, Whitman, W.C., Johnson, W.M., Tomczyk, J.A., and Silberstein, E., 8th Edition, 2017.
2. HVAC Systems and Equipment, McQuiston, F.C., Parker, J.D., and Spitler, J.D., 6th Edition, 2005.

Online Resources: https://onlinecourses.nptel.ac.in/noc19_me58/preview

3-0-0-6

ME584

Non-Linear Finite Element Methods

Course Outcomes:

CO1	Analyze nonlinear behavior in engineering systems.
CO2	Formulate nonlinear finite element equations for solids and structures.
CO3	Apply numerical solution strategies for nonlinear FEM problems.
CO4	Analyze geometric, material, and contact nonlinearities using FEM.
CO5	Solve advanced nonlinear Multiphysics problems relevant to intelligent mechanical systems.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	1	3
CO3	3	-	3
CO4	3	-	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Nonlinear Analysis: Classification of nonlinearities: material, geometric, boundary, contact; Review of linear FEM assumptions and limitations;

Kinematics of large deformation; Stress and strain measures (GreenAlmansi); Virtual work and weak form for nonlinear problems; Total Lagrangian -Lagrange, vs Updated Lagrangian formulations.

Nonlinear Material Models: Elastic-plastic behaviour: yield criteria, flow rules,

hardening laws; Hyperelastic materials: Mooneymodels; Viscoelastic and viscoplastic models; Damage and failure models -Rivlin, Neo-Hookean, Ogden

(introductory).

Solution Techniques for Nonlinear FEM: Incremental-iterative methods; Newton-Raphson and modified Newton methods; Line search and arc-length methods; Convergence criteria and numerical stability; Time integration schemes for nonlinear dynamics.

Geometric Nonlinearity and Stability: Large displacement and large rotation

problems; Nonlinear truss, beam, plate, and shell elements; Buckling and postanalysis; Snap-through and snap-back behaviour. -buckling

Contact and Constraint Nonlinearities: Contact kinematics and constraint enforcement; Penalty method, Lagrange multipliers, augmented Lagrangian; Frictional contact models; Self-contact and multi-body contact.

Text Books:

1. Nonlinear Finite Elements for Continua and Structures, Belytschko, T., Liu, W.K., Moran, B..

Reference Books:

1. Nonlinear Solid Mechanics, Holzapfel, G.A., 1st Edition, 2000.
2. Nonlinear Finite Element Analysis of Solids and Structures, Crisfield, M.A., 2nd Edition, 1997.

Online Resources: https://nptel.ac.in/courses/112106130

3-0-0-6

ME586

Turbulent Flows

Course Outcomes:

CO1	Analyze physical mechanisms and statistical nature of turbulent flows.
CO2	Analyze turbulent flows using statistical and theoretical frameworks.
CO3	Apply RANS-based turbulence models for engineering flow problems.
CO4	Evaluate advanced turbulence modeling approaches such as LES and DNS.
CO5	Solve real-world turbulent flow problems using CFD techniques.

Course Articulation Matrix:

COs	POs		
	PO1	PO2	PO3
CO1	2	-	2
CO2	3	1	3
CO3	3	-	3
CO4	3	-	3
CO5	3	1	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Turbulence: Characteristics of turbulent flows; Energy cascade and Kolmogorov hypotheses; Engineering relevance of turbulent flows.

Statistical Description of Turbulence: Reynolds decomposition; Time and ensemble averaging; Turbulence statistics: mean, RMS, correlations; Reynolds stresses and closure problem; Homogeneous and isotropic turbulence; Turbulent kinetic energy and dissipation.

Turbulent Boundary Layers & Shear Flows: Turbulent boundary layers over flat plates; Law of the wall and velocity profiles; Turbulent mixing layers, jets, and wakes; Free shear flows; Applications in propulsion, cooling, and mixing systems.

Turbulence Modeling – RANS Approaches: Need for turbulence models; Eddy viscosity concept; Algebraic models; Oneω, SST); Reynolds Stress Models (RSM); Model limitations and validation.-equation and two-equation models (k -ε, k-

Advanced Turbulence Modeling – LES & DNS: Large Eddy Simulation (LES) concepts; Sub-grid scale (SGS) models; Direct Numerical Simulation (DNS); Hybrid RANS-LES approaches; Computational requirements and challenges; Applications in intelligent and high-fidelity simulations.

Text Books:

1. Turbulent Flows, Pope, S, B.

Reference Books:

1. Turbulence: An Introduction for Scientists and Engineers, Davidson, P.A., 2nd Edition, 2015.
2. Turbulence Modeling for CFD**,** Wilcox, D.C., 3rd Edition, 2006.

Online Resources: https://nptel.ac.in/courses/101106060

3-0-0-6

ME588

Bio-inspired Designs

Course Outcomes:

CO1	Analyze principles of biological systems relevant to engineering design.
CO2	Analyze biological materials, structures, and mechanisms for engineering applications.
CO3	Apply bio-inspired design methodologies to intelligent mechanical systems.
CO4	Model, simulate, and optimize bio-inspired designs using computational tools.
CO5	Design innovative, sustainable, and intelligent systems inspired by nature.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	1	3
CO3	3	-	3
CO4	3	2	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Bio-Inspired Design & Biomimicry: Evolution of bio-inspired engineering; Biomimicry, bio-inspiration, and bio-integration; Biological systems vs engineered systems; Levels of bio-inspiration: organism, behavior, ecosystem; Design challenges in intelligent mechanical systems.

Biological Materials and Structures: Hierarchical structures in nature; Natural materials: bone, wood, nacre, spider silk; Structure–property relationships; Lightweight and high-strength bio-structures; Bio-inspired composites and metamaterials.

Bio-Inspired Mechanisms and Locomotion: Biological joints, muscles, and compliant mechanisms; Bio-inspired actuators and soft mechanisms; Locomotion strategies: walking, flying, swimming, crawling; Bio-inspired robotics and mechatronic systems.

Bio-Inspired Fluid and Thermal Systems: Flow control inspired by birds, fish, and insects; Drag reduction and turbulence control in nature; Heat transfer mechanisms in biological systems; Passive cooling and thermal regulation.

Design Methodologies & Computational Tools: Bio-inspired design process and abstraction; TRIZ and bio-TRIZ; Generative and evolutionary design; FEM/CFD modelling of bio-inspired systems; Optimization techniques for bio- inspired designs.

Text Books:

1. Biomimetics: Biologically Inspired Technologies, Cohen, Y.

Reference Books:

1. Bio-Inspired Design: Computational Methods and Applications, Helms, M., Vattam, S., and Goel, A.K., 1st Edition, 2009.
2. Nature-Inspired Design of Smart Materials, Bhushan, B., 1st Edition, 2016.

Online Resources: https://nptel.ac.in/courses/107104076

Advanced Mechanical Vibration **3-0-0-6 ME590**

Course Outcomes:

CO1	Evaluate advanced vibration theory and modelling of mechanical systems.
CO2	Analyze multi-degree-of-freedom and continuous vibrating systems.
CO3	Evaluate nonlinear and random vibration behavior in engineering systems.
CO4	Apply vibration control and monitoring techniques for intelligent systems.
CO5	Use computational and experimental tools for vibration analysis and diagnostics.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3

CO1	3	1	3
CO2	3	1	3
CO3	3	1	3
CO4	3	1	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals and Review: Review of single and multi-degree-of-freedom systems; Free and forced vibration analysis.; Damping models and energy methods.

Advanced Analytical Methods: Matrix methods in vibration analysis.; Modal analysis and orthogonality conditions; Approximate methods: Rayleigh's method, Dunkerley's method, Holzer's method.

Continuous Systems and Wave Propagation: Vibration of strings, rods, beams, and plates; Longitudinal, torsional, and transverse vibrations; Wave propagation in elastic media.

Nonlinear Vibrations: Sources of nonlinearity in mechanical systems; Perturbation methods, harmonic balance, and numerical techniques; Chaos and bifurcation in mechanical vibrations.

Vibration Measurement and Control: Experimental techniques: FFT analyzers, modal testing, sensors; Active and passive vibration control; Smart materials and intelligent damping systems.

Text Books:

1. Mechanical Vibrations, Rao, S.S., 6th Edition.

Reference Books:

1. Engineering Vibration, Inman, D.J., 4th Edition, 2013.
2. Advanced Vibrations, Thompson, W.T., 1st Edition, 1993.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc21_ae15/preview

3-0-0-6

ME592

Human–Machine Interaction

Course Outcomes:

CO1	Analyze principles of human–machine interaction and human factors engineering.
CO2	Analyze human cognitive, physical, and perceptual aspects in mechanical systems.
CO3	Design ergonomic and safe interfaces for intelligent mechanical systems.
CO4	Apply sensing, control, and AI techniques to develop adaptive HMI systems.
CO5	Evaluate advanced HMI applications considering ethics, safety, and sustainability.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	1	3
CO3	3	-	3
CO4	3	-	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Human–Machine Interaction: Evolution of HMI and human centered design; Human–machine systems in mechanical engineering; Role of HMI in intelligent mechanical systems; Safety, usability, and reliability.

Human Factors & Ergonomics: Anthropometry and biomechanics; Cognitive ergonomics and mentaproprioception; Human error, fatigue, and stress; Ergonomic design of workstations l workload; Human perception: vision, hearing, touch, and machines.

Sensors, Interfaces & Feedback Modalities: Human input devices: switches, joysticks, touch, gesture; Biosignals: EMG, EEG, ECG (introductory); Output modalities: visual, auditory, haptic feedback; Multimodal interfaces.

Human–Robot and Human–Automation Interaction: Levels of automation and autonomy; Shared control and supervisory control; Human–robot collaboration (HRC) and cobots; Trust, transparency, and explainability.

Intelligent & Adaptive HMI Systems: AI-based user modeling and personalization; Context-aware and adaptive interfaces; Machine learning for intent recognition; Digital twins and virtual interfaces.

Text Books:

1. Human–Computer Interaction, Turk, M., & Medioni, G. **Reference Books:**

1. The Handbook of Human–Machine Interaction, Boy, G.A., 1st Edition, 2011.
2. Designing the User Interface, Shneiderman, B., Plaisant, C., Cohen, M., Jacobs, S., Elmqvist, N., and Diakopoulos, N., 6th Edition, 2016.

Online Resources:

1. https://nptel.ac.in/courses/110105162

3-0-0-6

ME594

Instrumentation and Measurement Systems

Course Outcomes:

CO1	Analyze principles, characteristics, and performance of measurement systems.
CO2	Analyze measurement errors, uncertainty, and experimental data statistically.
CO3	Apply appropriate sensors and transducers for mechanical system measurements.
CO4	Design signal conditioning and data acquisition systems for accurate measurements.
CO5	Develop intelligent and IoT-enabled instrumentation systems for modern applications.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	3
CO2	3	-	3

CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Measurement Systems: Measurement philosophy and termnology; Functional elements of measurement systems; Static and dynamic

characteristics of instruments; Accuracy, precision, resolution, sensitivity; Calibration standards and traceability; Errors and error sources in measurements.

Measurement Uncertainty and Data Analysis: Types of errors: systematic and random; Uncertainty analysis and propagation of errors; Statistical treatment of experimental data; Regression and curve fitting; Standards for uncertainty evaluation (ISO/GUM – overview); Reliability and repeatability in measurements.

Sensors and Transducers for Mechanical Systems: Measurement of displacement, velocity, acceleration; Force, torque, pressure, and flow measurement; Temperature and heat flux sensors; Strain gauges and piezoelectric sensors; Smart and MEMS-based sensors; Sensor selection and integration.

Signal Conditioning and Data Acquisition: Signal conditioning: amplification, filtering, isolation; Analog-to-digital and digital-to-analog conversion; Sampling theory and aliasing; Data acquisition systems (DAQ); Noise sources and noise reduction techniques; Instrumentation interfaces and communication protocols.

Intelligent Instrumentation and Measurement Systems: Virtual instrumentation (LabVIEW/MATLAB); Embedded measurement systems; IoT-based measurement and monitoring; Sensor fusion and multi-sensor systems;

Intelligent sensors with onboard processing.

Text Books:

1. Measurement Systems: Application and Design, Deobelin, E., O.

Reference Books:

1. Principles of Measurement Systems, Bentley, J.P., 4th Edition, 2005.

2. Electronic Instrumentation and Measurements, Raghuwanshi, M., and Raghuwanshi, R., 1st Edition, 2014.

Online Resources: https://onlinecourses.nptel.ac.in/noc26_ee01/preview

3-0-0-6

ME596

Mechatronics System Design

Course Outcomes:

CO1	Analyze and model complex multi-domain systems (mechanical, electrical, fluidic) using a unified approach.
CO2	Select and integrate advanced sensors and smart actuators for specific intelligent system requirements.
CO3	Design and implement embedded control logic using microcontrollers, PLCs, or Real-Time Operating Systems (RTOS).
CO4	Apply optimization techniques and AI-based decision-making to mechatronic system architectures.
CO5	Develop a functional mechatronic prototype addressing real-world industrial or societal challenges.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	-	3
CO3	3	-	3
CO4	3	-	3
CO5	3	1	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to System Design Modeling: Evolution of Mechatronics; The "V-Model" of system design; Modeling of Physical Systems: Bond Graph modeling, State-space representation; Electromechanical analogies and thermal-fluidic system modeling.

Sensing and Perception: High-precision sensors: Lidar, Ultrasonic, Vision-based sensing; Signal Conditioning: Operational Amplifiers, Filtering (Analog & Digital); Data Acquisition Systems (DAQ) and Sensor Fusion algorithms (Kalman Filters).

Actuation and Drive Systems: Alloys); Drive Electronics: PWM techniques, HSmart Actuators: Piezoelectric, SMA -Bridge circuits, Brushless DC (Shape Memory (BLDC) motor control; Fluid power systems and proportional valves in mechatronics.

Control Architecture & Embedded Systems: Real-time systems and RTOS fundamentals; Communication Protocols: I2C, SPI, CAN bus, and Industrial Ethernet; PLC programming (Ladder logic) vs. Microcontroller-based control (Arduino/STM32/Raspberry Pi).

Intelligent Systems & Integration: Introduction to Soft Computing in Mechatronics: Fuzzy Logic and Neural Networks; Case Studies: Autonomous Mobile Robots, Quadcopters, and Smart Manufacturing Cells; Design for Manufacturability (DfM) and Reliability in Mechatronic products.

Text Books:

1. Design of Mechatronic Systems, Janschek, K.

Reference Books:

1. Mechatronic Systems: Devices, Design, Control, Operation and Monitoring, Alciatore, D.G., and Histand, M.B., 2nd Edition, 2011.
2. Introduction to Mechatronics and Measurement Systems, Alciatore, D.G., and Histand, M.B., 4th Edition, 2011.

Online Resources: https://onlinecourses.nptel.ac.in/noc21_me27/preview

Credits 3-0-0-6

ME598

Computational Fluid Dynamics

Course Outcomes:

CO1	Derive and categorize the governing equations of fluid flow and heat transfer (Navier-Stokes equations).
CO2	Apply discretization techniques (FDM, FVM) to transform partial differential equations into solvable algebraic forms.

CO3	Evaluate and select appropriate turbulence models and boundary conditions for complex industrial flows.
CO4	Utilize commercial CFD software (ANSYS Fluent/OpenFOAM) to conduct high-fidelity simulations.
CO5	Integrate intelligent data-driven approaches (like Reduced Order Modeling) to optimize fluid system designs.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	-	3
CO3	3	-	3
CO4	3	2	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Governing Equations and Mathematical Behavior: Review of Fluid Mechanics: Continuity, Momentum, and Energy equations; Navier-Stokes equations: Conservation form vs. Non-conservation form; Mathematical classification of PDEs: Elliptic, Parabolic, and Hyperbolic equations.

Discretization Techniques: Finite Difference Method (FDM): Derivation of forward, backward, and central difference schemes; Accuracy and truncation errors; Finite Volume Method (FVM): Discretization of diffusion and convection-diffusion problems; Pressure-Velocity Coupling: SIMPLE, SIMPLER, and PISO algorithms.

Gridding and Convergence: Mesh Generation: Structured, Unstructured, and Polyhedral meshes; Mesh quality metrics (Aspect ratio, Skewness); Stability Analysis: Von Neumann stability, CFL condition; Convergence criteria and error estimation (Iteration error vs. Discretization error).

Turbulence Modeling and Advanced Topics: Characteristics of Turbulence; Reynolds Averaged Navier-Stokes (RANS) equations.; Turbulence Models: k-ϵ, k-ω SST, and Large Eddy Simulation (LES) overview; Boundary Layer Modeling: Wall functions and y+ requirements.

Intelligent CFD and Applications: Data-Driven Fluid Dynamics: Introduction to Physics-Informed Neural Networks (PINNs); Reduced Order Modeling

(ROM) for real-time fluid simulation in intelligent systems.

Text Books:

1. Computational Fluid Dynamics: The Basics with Applications, Anderson, J., D.

Reference Books:

1. An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Versteeg, H.K., and Malalasekera, W., 2nd Edition, 2007.
2. Computational Methods for Fluid Dynamics, Ferziger, J.H., Perić, M., and Street, R.L., 4th Edition, 2020.

Online Resources: https://nptel.ac.in/courses/112105045

3-0-0-6

ME600 Rotor Dynamics

Course Outcomes:

CO1	Explain the fundamentals of rotor–bearing interaction, flexural vibration, and critical speeds of shafts.
CO2	Analyze the effects of anisotropic bearings, asymmetric shafts, gyroscopic forces, and aerodynamic influences on rotor stability.
CO3	Model rotor systems using equivalent discrete methods, geared and branched configurations, and evaluate fluid film bearing characteristics.
CO4	Apply balancing techniques for rigid and flexible rotors and demonstrate practical approaches to vibration control.
CO5	Evaluate condition monitoring strategies and utilize measurement techniques for fault diagnosis and predictive maintenance of rotating machinery.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	3	1	3
CO2	3	-	3
CO3	3	-	3
CO4	3	-	3
CO5	3	3	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Fundamentals of Rotor Dynamics: Introduction to rotor dynamics covering rotorspeeds.– bearing interaction, flexural vibration of shafts, and determination of critical

Advanced Rotor–Bearing Effects: Study of anisotropic bearings, unbalanced

response of asymmetric shafts, gyroscopic effects in highaerodynamic influences on stability. -speed rotors, and

System Modeling & Bearings: Modeling of rotor systems using equivalent discrete

methods, geared and branched configurations, and analysis of fluid film bearings with steady-state characteristics.

Rotor Balancing & Control: Balancing of rotors including rigid rotor balancing with single- and two-plane methods, flexible rotor balancing using modal techniques, and nonlinear rotor dynamics with vibration control strategies.

Condition Monitoring & Intelligent Applications: Condition monitoring of rotating machinery with measurement techniques, signal processing methods, AI-based fault diagnosis, predictive maintenance, digital twin concepts, and IoTenabled real-time monitoring.

Text Books:

1. Rajiv Tiwari, Rotor Systems: Analysis and Identification, CRC Press, Boca Raton, 2017.
2. J. S. Rao, Rotor Dynamics, Third ed., New Age, New Delhi, 1996.

Reference Books:

1. 1. M. J. Goodwin, Dynamics of Rotor-Bearing Systems, Unwin Hyman, Sydney, 1989.
2. 2. Agnieszka Muszyńska, Rotordynamics, CRC Press, Boca Raton, 2005.

Online Resources:

1. https://nptel.ac.in/courses/112103024

3-0-0-6

ME602 Scientific Machine Learning

Course Outcomes:

CO1	Examine the foundations of scientific machine learning that blend physics-based modelling with modern ML approaches.
CO2	Develop deep understanding of data-driven modelling of dynamical systems and mechanical processes.
CO3	Explore physics-informed neural networks (PINNs), operator learning, and surrogate modelling.
CO4	Quantify uncertainty and ensure robustness in SciML models.
CO5	Implement SciML techniques in real-world mechanical systems.

Course Articulation Matrix:

COs	**POs**		
	PO1	PO2	PO3
CO1	2	1	2
CO2	3	-	3
CO3	3	-	3
CO4	3	1	3
CO5	3	2	3

1 – Low 2 – Medium 3 – High

Detailed Syllabus:

Introduction to Scientific Machine Learning: ML vs Scientific ML vs Traditional Numerical Analysis; Workflow: data, physics priors, simulation, model learning; Applications: fluid dynamics, structural mechanics, thermal systems, robotics.

Data-Driven Modelling of Dynamical Systems: Black-box, gray-box, and hybrid modelling; State estimation and system identification; Sparse Identification of Nonlinear Dynamics (SINDy); Koopman operator theory & dynamic mode decomposition (DMD); Time-series modelling for mechanical systems

Physics-Informed Neural Networks: Concept of embedding physical laws into neural networks; Training PINNs for ODEs and PDEs; structural dynamics, and thermal systems. Applications in fluid mechanics,

Surrogate Modelling & Reduced-Order Models: Polynomial chaos expansion (PCE); Gaussian Process Regression (GPR) & Kriging; Projection-based ROMs: POD, Galerkin projection; Nonlinear ROMs and ML-based ROMs.

Scientific Deep Learning & Operator Learning: DeepONet, Fourier Neural Operators, Neural ODEs; Learning solution operators for PDEs; Neural differential equations; Multi-fidelity & transfer learning in scientific models.

Text Books:

1. Scientific Machine Learning: Theory & Applications, Kutz, J.N., and Brunton, S., Cambridge English, 2019.
2. Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control, Brunton, S., and Kutz, J.N.

Reference Books:

3. Physics-Informed Machine Learning, Karniadakis, G.E., Kevrekidis, I.G., Lu, L., Perdikaris, P., Wang, S., and Yang, L., 1st Edition, 2024.
4. Machine Learning for Modeling and Control of Dynamical Systems, Brunton, S.L., and Kutz, J.N., 1st Edition, 2019.

Online Resources:

1. https://nptel.ac.in/courses/106106198