VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE
(VJTI)
MATUNGA, MUMBAI 400 019
(Autonomous Institute affiliated to the University of Mumbai)

Curriculum
(Scheme of Instruction & Evaluation and Course Contents)

For

Two Year Post Graduate Programme Leading to
Master of Technology (M. Tech.) Degree in ***Production & Industrial Engineering***

Implemented from the batch admitted in first year, 2025-26

Vision and Mission of the Institute

Vision

To establish global leadership in the field of Technology and develop competent human resources for providing service to society.

Mission

- To provide students with comprehensive knowledge of principles of engineering with a multi-disciplinary approach that is challenging
- To create an intellectually stimulating environment for research, scholarship, creativity, innovation, and professional activity.
- To foster relationships with other leading institutes of learning and research, alumni and industries to contribute to National and International development.

Vision and Mission of the Department

Vision

To develop technically competent and disciplined production engineers with creativity, comprehension and managerial skills to serve as a preferred provider of Manufacturing and Industrial Engineering students and services that satisfy the changing needs of all customer segments.

Mission

- Inculcate and develop the students who will be able to design and manufacture innovative, environmentally friendly, ergonomic and cost-effective quality products and services.
- Enhance the technical quality of the students to fulfil the challenges, competitions and opportunities in Production/ Industrial Engineering.
- Prepare the students to solve community-related engineering problems and other complex problems by means of inculcating technical managerial skills.
- Strive continuously to pursue excellence in all the areas of Manufacturing/ Industrial and enhance the department-industry/research centre interaction by means of training, internship and student projects to solve industrial problems.

Credit Framework for PG Programme in Production & Industrial Engineering
Semester I

S. No	Course Code	Course Name	L	T	P	Hr	Cr	Examination Weightage in %		
								TA	MST	ESE
1	PEPI5001S	Advanced Operations Research	3	1	0	4	4	20	30	50
2	PEPI5011S	Additive Manufacturing	3	0	0	3	3	20	30	50
3	PEPI5012T	Supply Chain and Logistics Management	3	1	0	4	4	20	30	50
4		Program Elective – 1	3	0	0	3	3	20	30	50
5		Program Elective – 2	3	0	0	3	3	20	30	50
6		Open Elective – 1	3	0	0	3	3	20	30	50
7	PEPI5071L	Advanced Operations Research Laboratory	0	0	2	2	1	ISCE: 60		40
8	PEPI5072L	Industrial Engineering Laboratory	0	0	2	2	1	ISCE: 60		40
9	PEPI5073L	Computer Aided Analysis Laboratory	0	0	2	2	1	ISCE: 60		40
10		Liberal Learning – 1	0	0	2	2	1	100% ISCE		
		Total	**18**	**2**	**8**	**28**	**24**			

Abbreviations:
L: Lecture, **T**: Tutorial, **P**: Practical, **Cr:** Credit **TA**: Teacher Assessment, **MST**: Mid-Semester Test, **ESE**: End Semester Examination, **ISCE:** In Semester Continuous Evaluation

Program Elective Courses (PEC – 1) *(Advanced Manufacturing & Materials)*		
S. No.	**Course Code**	**Course Title**
1	PEPI5021S	Lasers in Manufacturing
2	PEPI5022S	Composite Materials and Processing
3	PEPI5023S	Finite Element Method (FEM) in Manufacturing

Program Elective Courses (PEC – 2) *(Industrial Systems & Optimization)*		
S. No.	**Course Code**	**Course Title**
1	PEPI5031S	Industrial Engineering
2	PEPI5032S	Meta-Heuristic Optimization Techniques
3	PEPI5033S	Reliability Engineering and Maintenance

Open Elective Course (OEC – 1): (PEPM5061S) Entrepreneurship Development
Liberal Learning – 1 (**PEPM5081L):** Strategic Thinking & Problem-Solving Skills

Credit Framework for PG Programme in Production & Industrial Engineering
Semester II

S. No	Course Code	Course Name	L	T	P	Hr	Cr	Examination Weightage in %		
								TA	MST	ESE
1	PEPI5002S	Research Methodology and IPR	3	0	0	3	3	20	30	50
2	PEPI5013T	Smart Manufacturing	3	1	0	4	4	20	30	50
3	PEPI5014T	Production and Operations Management	3	1	0	4	4	20	30	50
4		Program Elective – 3	3	0	0	3	3	20	30	50
5		Program Elective – 4	3	0	0	3	3	20	30	50
6		Open Elective – 2	3	0	0	3	3	20	30	50
7	PEPI5074L	Advanced Manufacturing Laboratory	0	0	2	2	1	ISCE: 60		40
8	PEPI5075L	Product Lifecycle Management Lab	0	0	2	2	1	ISCE: 60		40
9	PEPI5076L	Manufacturing Processes Simulation Laboratory	0	0	2	2	1	ISCE: 60		40
10		Liberal Learning – 2	0	0	2	2	1	100% ISCE		
		Total	**18**	**2**	**8**	**28**	**24**			

Abbreviations:
L: Lecture, **T**: Tutorial, **P**: Practical, **Cr:** Credit **TA**: Teacher Assessment, **MST**: Mid-Semester Test, **ESE**: End Semester Examination, **ISCE:** In Semester Continuous Evaluation

Program Elective Courses (PEC – 3) *(Automation & Control)*		
S. No.	**Course Code**	**Course Title**
1	PEPI5041S	Robotics in Manufacturing
2	PEPI5042S	Product Lifecycle Management (PLM)
3	PEPI5043S	Autonomous Systems and Industry 5.0

Program Elective Courses (PEC – 4) *(Quality & Sustainability)*		
S. No.	**Course Code**	**Course Title**
1	PEPI5051S	Circular Manufacturing and Sustainability
2	PEPI5052S	Energy Management in Industries
3	PEPI5053S	Economics, Finance, Accounting and Costing

Open Elective Course (OEC – 2): (PEPI5062S) Industrial Safety, Health, and Risk Assessment
Liberal Learning – 2 (**PEPI5082LA):** Professional Ethics in Engineering

Credit Framework for PG Programme in Production & Industrial Engineering
Semester III

S. No	Course Code	Course Name	L	T	P	Cr	Examination Weightage in %
1	PEPI5091D	Project Stage – I				5	100% ISCE
2	PEPI5092D	Project Stage – II				5	100% ISCE
3	PEPI51xxS	Self-Learning Course – I	1	0	0	1	100% ESE of 3 hours or Credit Transfer
4	PEPI52xxS	Self-Learning Course – II	1	0	0	1	100% ESE of 3 hours or Credit Transfer
5	PEPM5301S	Effective Business Communication (MNC)	2	0	0	0	100% ESE of 3 hours or Credit Transfer
		Total				**12**	

Abbreviations:
ISCE: In Semester Continuous Evaluation

Self-Learning Course – I		
S. No.	**Course Code**	**Course Title**
1	PEPI5101S	Micro and Nano Manufacturing Systems
2	PEPI5102S	Sustainable Remanufacturing & E-Waste Management
3	PEPI5103S	Machine Tool Metrology and Calibration

Self-Learning Course – II		
S. No.	**Course Code**	**Course Title**
1	PEPI5201S	Design Thinking and Systematic Innovation (TRIZ)
2	PEPI5202S	Six Sigma DMAIC Methodology
3	PEPI5203S	Human Factors & Cognitive Ergonomics in Smart Workplaces

Credit Framework for PG Programme in Production & Industrial Engineering
Semester IV

S. No	Course Code	Course Name	Cr	Examination Weightage in %
1	PEPI5093D	Project Stage – III	5	100% ISCE
2	PEPI5094D	Project Stage – IV	7	100% ISCE
		Total	**12**	

Abbreviations:
ISCE: In Semester Continuous Evaluation

Semester I

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5001S	
Course Title	Advanced Operations Research	

Course outcomes: On the completion of this course, the learner will able to

1. Formulate and solve complex optimization problems in industrial systems.
2. Apply decomposition and heuristic techniques for large-scale problems.
3. Analyze uncertainty and multi-objective trade-offs in industrial decision-making.
4. Use simulation and queuing models to design efficient production & service systems.
5. Apply OR tools to real-world production, logistics, and supply chain case studies.

Syllabus

1. Advanced Linear & Nonlinear Programming

- Review of classical OR: simplex, duality, sensitivity analysis.
- Revised simplex, interior point methods.
- Large-scale linear programming (decomposition: Dantzig-Wolfe, Benders).
- Nonlinear programming: convexity, Kuhn-Tucker conditions, penalty & barrier methods.
- Applications in production planning and process optimization.

2. Integer & Combinatorial Optimization

- Branch and bound, cutting plane, branch and cut.
- Mixed-integer programming applications in facility layout and scheduling.
- Combinatorial optimization: traveling salesperson problem (TSP), vehicle routing, knapsack problem.

3. Advanced Network Models

- Review: shortest path, maximum flow, minimum cost flow.
- Multicommodity flows, project crashing, and time-cost trade-offs.

	• Network design problems in logistics & supply chain. • Dynamic programming applications in production and distribution.
4.	**Game Theory & Multi-Criteria Decision Making** • Non-cooperative & cooperative games, Nash equilibrium. • Decision-making under uncertainty and risk. • Multi-objective optimization: Goal programming, Weighted Sum & ε-constraint methods. • MCDM techniques: AHP, TOPSIS, VIKOR, fuzzy approaches
5.	**Queuing Models & Simulation** • Advanced queuing systems: M/G/1, G/M/1, networks of queues. • Applications in production lines, service centers, and inventory systems. • Discrete event simulation, Monte Carlo techniques. • Simulation modeling of manufacturing & logistics systems.
6.	**Specialized Applications in Industrial Engineering** • Supply chain optimization, production scheduling, and inventory control. • Reliability optimization & maintenance planning. • Case studies: OR in Industry 4.0, Smart Manufacturing, and AI-OR integration.

	References and Textbooks
1	**H.A. Taha** – *Operations Research: An Introduction* (Pearson)
2	**F.S. Hillier and G.J. Lieberman** – *Introduction to Operations Research* (McGraw-Hill)
3	**R. Panneerselvam** – *Operations Research* (PHI Learning)
4	**Kanti Swarup, P.K. Gupta, and Man Mohan** – *Operations Research* (S. Chand & Co.)
5	**Winston, W.L.** – *Operations Research: Applications and Algorithms* (Cengage Learning)

6	**S.D. Sharma** – *Operations Research* (Kedarnath Ramnath & Co.)
7	**J.K. Sharma** – *Operations Research: Theory and Applications* (Macmillan India)
8	**Phillips, Ravindran & Solberg** – *Operations Research: Principles and Practice* (Wiley)
9	**Mokhtar S. Bazaraa, John J. Jarvis, Hanif D. Sherali** – *Linear Programming and Network Flows* (Wiley)
10	**Ravindran, Phillips & Solberg** – *Operations Research: Principles and Practice* (Wiley)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5011S	
Course Title	Additive Manufacturing	

Course outcomes: On the completion of this course, the learner will able to

1. Understand AM principles, processes, and classifications
2. Analyze AM materials and their impact on process performance
3. Design optimized components for AM using DfAM strategies
4. Evaluate post-processing techniques and quality control in AM
5. Explore industrial applications and future advancements in AM

Syllabus

1. Introduction to Additive Manufacturing (AM)

- Fundamentals of AM, comparison with conventional manufacturing
- AM process chain: Design, material selection, process planning, post-processing
- AM standards and classifications

2. AM Processes and Technologies

- Vat Photopolymerization
- Material Jetting
- Binder Jetting
- Material Extrusion
- Powder Bed Fusion
- Sheet Lamination
- Directed Energy Deposition

3. Materials for Additive Manufacturing

- Polymers, metals, ceramics, and composites
- Powder characteristics and material properties
- Recycling and sustainability in AM materials

4. Design for Additive Manufacturing (DfAM)

- Topology optimization and generative design

	• Lattice structures, lightweighting, and part consolidation • CAD modeling, slicing, and process parameter optimization
5.	**Post-Processing and Quality Assurance** • Surface finishing, heat treatment, and defect mitigation • Mechanical properties and testing of AM parts • Process monitoring and in-situ inspection
6.	**Applications of Additive Manufacturing** • Aerospace, automotive, biomedical, and industrial sectors • Rapid prototyping, tooling, and direct digital manufacturing • Future trends: 4D printing, hybrid AM, bioprinting
	References and Textbooks
1	**Ian Gibson, David Rosen, Brent Stucker** – *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing* (Springer)
2	**Andreas Gebhardt** – *Understanding Additive Manufacturing* (Hanser Publishers)
3	**Amit Bandyopadhyay, Susmita Bose** – *Additive Manufacturing* (CRC Press)
4	**D.T. Pham, S.S. Dimov** – *Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling* (Springer)
5	**Christopher Barnatt** – *3D Printing: The Next Industrial Revolution* (ExplainingTheFuture.com)
6	**L. Lu, J. Fuh, Y.S. Wong** – *Laser Additive Manufacturing of High-Performance Materials* (Springer)
7	**Frank W. Liou** – *Rapid Prototyping and Engineering Applications: A Toolbox for Prototype Development* (CRC Press)
8	**Chee Kai Chua, Kah Fai Leong, Chu Sing Lim** – *Rapid Prototyping: Principles and Applications* (World Scientific)
9	**John O. Milewski** – *Additive Manufacturing of Metals: From Fundamental Technology to Rocket Nozzles, Medical Implants, and Custom Jewelry* (Springer)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5012T	
Course Title	Supply Chain and Logistics Management	

	Course outcomes: On the completion of this course, the learner will able to 1. Understand supply chain and logistics concepts, strategies, and key components 2. Optimize supply chain networks and facility locations for efficiency 3. Apply inventory control models and warehouse management techniques 4. Utilize digital tools and analytics for supply chain decision-making 5. Manage logistics operations and mitigate risks in global supply chains
	Syllabus
1.	**Introduction to Supply Chain and Logistics** • Fundamentals of supply chain management (SCM) and logistics • Supply chain components and key stakeholders • Logistics functions: inbound, outbound, and reverse logistics
2.	**Supply Chain Network Design and Optimization** • Facility location and network design strategies • Transportation and distribution network planning • Strategic sourcing and supplier selection
3.	**Inventory and Warehouse Management** • Inventory classification and control models (EOQ, JIT, VMI) • Warehouse layout, material handling, and automation • Demand forecasting techniques for inventory optimization
4.	**Supply Chain Analytics and Digitalization** • Role of data analytics and AI in SCM • Digital supply chain transformation (IoT, blockchain, Industry 4.0) • Performance measurement and KPI benchmarking

5.	L**ogistics and Transportation Management** • Modes of transportation and route optimization • Freight management and intermodal logistics • Green logistics and sustainability in supply chains
6.	R**isk Management and Global Supply Chains** • Supply chain risks and mitigation strategies • Resilient supply chain frameworks and disruption management • Case studies on global supply chain challenges
	References and Textbooks
1	**Sunil Chopra, Peter Meindl** – *Supply Chain Management: Strategy, Planning, and Operation* (Pearson)
2	**David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi** – *Designing and Managing the Supply Chain* (McGraw-Hill)
3	**Martin Christopher** – *Logistics & Supply Chain Management* (Pearson)
4	**John J. Coyle, C. John Langley, Robert A. Novack, Brian J. Gibson** – *Supply Chain Management: A Logistics Perspective* (Cengage Learning)
5	**Jeremy F. Shapiro** – *Modeling the Supply Chain* (Cengage)
6	**Mohamed Y. Jaber** – *Inventory and Supply Chain Management with Forecast Updates* (Springer)
7	**Sridhar Tayur, Ram Ganeshan, Michael Magazine** – *Quantitative Models for Supply Chain Management* (Springer)
8	**Donald Waters** – *Logistics: An Introduction to Supply Chain Management* (Palgrave Macmillan)
9	**Nada R. Sanders** – *Big Data Driven Supply Chain Management* (Pearson)
10.	**Bowersox, Closs, Cooper, Bowersox** – *Supply Chain Logistics Management* (McGraw-Hill)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5021S	
Course Title	Lasers in Manufacturing	

Course outcomes: On the completion of this course, the learner will able to

1. Understand principles of laser generation, beam characteristics, and energy-material interactions
2. Apply lasers for cutting, welding, drilling, surface treatment, and additive manufacturing
3. Analyze thermal effects, metallurgical changes, and microstructural transformations.
4. Evaluate laser-based hybrid manufacturing processes
5. Explore industrial case studies of laser processing in automotive, aerospace, and medical industries

Syllabus

1. Fundamentals of Lasers

- Principles of laser action: population inversion, stimulated emission
- Types of lasers: CO_2, Nd:YAG, fiber, diode lasers
- Beam characteristics and optics for laser systems

2. Laser–Material Interaction

- Absorption, reflection, conduction in metals, polymers, ceramics
- Thermal models for laser heating
- Heat-affected zone (HAZ) analysis

3. Laser Processing Techniques

- Laser cutting, drilling, and welding
- Laser surface hardening, alloying, and cladding
- Micro-machining applications

4. Laser Additive & Hybrid Manufacturing

- Directed Energy Deposition (DED) with lasers
- Selective Laser Melting (SLM) and sintering

	• Laser-arc hybrid processes
5.	**Metrology and Quality Control in Laser Manufacturing** • Monitoring, sensors, and feedback systems • Non-destructive evaluation of laser-processed parts
6.	**Applications and Case Studies** • Aerospace: turbine blades, engine components • Automotive: gear hardening, body welding • Medical: stents, implants, surgical tools
	References and Textbooks
1	**Steen, W.M. & Mazumder, J**. – *Laser Material Processing* (Springer)
2	**Dahotre, N.B.** – *Laser Fabrication and Machining of Materials* (Springer)
3	**Ready, J.F.** – *Industrial Applications of Lasers* (Academic Press)
4	**Davis, J.R.** – *Laser Processing of Engineering Materials* (ASM International)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5022S	
Course Title	Composite Materials and Processing	

Course outcomes: On the completion of this course, the learner will able to

1. Understand the types, structure, and properties of composite materials
2. Apply different composite manufacturing methods
3. Evaluate mechanical performance, testing, and failure mechanisms
4. Explore applications in aerospace, automotive, and defense
5. Analyze sustainability and recycling strategies for composites

Syllabus

1. Introduction to Composites

- Classification: polymer, metal, ceramic matrix composites
- Fiber types: glass, carbon, aramid
- Matrix materials and bonding mechanisms

2. Composite Manufacturing Processes

- Hand layup, spray-up, filament winding
- Resin transfer molding, compression molding, autoclave techniques
- Additive manufacturing of composites

3. Mechanical Properties and Testing

- Tensile, flexural, impact, fatigue properties
- Fracture mechanics of composites
- Non-destructive testing methods

4. Design and Analysis of Composites

- Micromechanics and macromechanics
- Rule of mixtures and Halpin–Tsai models
- Finite Element Analysis for composites

5. Applications

- Aerospace: aircraft structures, rotor blades

	• Automotive: lightweight components, crashworthiness • Energy: wind turbine blades, pressure vessels
6.	**Recent Advances** • Nano-composites • Green composites and recycling challenges
	References and Textbooks
1	**Mallick, P.K.** – *Fiber-Reinforced Composites* (CRC Press)
2	**Agarwal, B.D. & Broutman, L.J.** – *Analysis and Performance of Fiber Composites* (Wiley)
3	**Daniel, I.M. & Ishai, O.** – *Engineering Mechanics of Composite Materials* (Oxford)
4	**Chawla, K.K.** – *Composite Materials: Science and Engineering* (Springer)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5023S	
Course Title	Finite Element Methods (FEM) in Manufacturing	

	Course outcomes: On the completion of this course, the learner will able to 1. Understand FEM fundamentals and discretization techniques 2. Formulate and solve 1D, 2D, and 3D FEM models for manufacturing applications 3. Apply FEM to machining, forming, and heat transfer problems 4. Use FEM software for simulation and validation of industrial problems 5. Analyze case studies in metal cutting, forming, and additive manufacturing
	Syllabus
1.	**Introduction to FEM** • Mathematical formulation and variational principles • Shape functions, interpolation, and discretization • Assembly and solution procedures
2.	**Finite Elements for Structural Problems** • Truss, beam, and frame elements • Plate and shell elements • Static, dynamic, and thermal analysis
3.	**Manufacturing Applications** • Metal cutting simulations • Sheet metal forming, extrusion, and forging • Welding and additive manufacturing heat transfer models
4.	**Numerical Methods in FEM** • Gauss elimination, LU decomposition • Numerical integration (Gauss quadrature) • Error estimation and convergence
5.	**Software Tools for FEM** • Introduction to ANSYS, ABAQUS, DEFORM, COMSOL

	• Pre-processing, meshing, boundary conditions • Post-processing and validation
6.	**Case Studies and Projects** • FEM in tool design, residual stress analysis • Application in AM: thermal distortion and warping
	References and Textbooks
1	**Chandrupatla & Belegundu** – *Introduction to Finite Elements in Engineering* (Pearson)
2	**Reddy, J.N.** – *An Introduction to the Finite Element Method* (McGraw-Hill)
3	**Cook, R.D.** – *Concepts and Applications of Finite Element Analysis* (Wiley)
4	**Zienkiewicz, O.C. & Taylor, R.L.** – *The Finite Element Method* (McGraw-Hill)
5	**Bathe, K.J.** – *Finite Element Procedures* (Prentice Hall)
6	**Chandrupatla & Belegundu** – *Introduction to Finite Elements in Engineering* (Pearson)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5031S	
Course Title	Industrial Engineering	

	Course outcomes: On the completion of this course, the learner will able to 1. Apply methods engineering, work study, and ergonomics in industrial systems 2. Analyze facility layout, plant location, and material handling 3. Use productivity improvement techniques and lean manufacturing tools 4. Evaluate human factors, safety, and ergonomics in workplace design 5. Integrate modern industrial engineering practices for system optimization
	Syllabus
1.	**Introduction to Industrial Engineering** • Role and scope of IE • Productivity measurement and improvement techniques
2.	**Work System Design** • Method study, time study, work sampling • Ergonomics and human factors in work design • Workplace design principles
3.	**Facilities Planning** • Plant location and layout design • Material handling systems and selection • Computer-aided layout techniques
4.	**Production and Service Systems** • Lean manufacturing and Six Sigma • Value stream mapping (VSM) • Industrial case studies
5.	**Industrial Safety and Human Factors** • Occupational health and safety

	• Cognitive ergonomics and workplace stress • Standards and safety practices
6.	**Recent Trends** • Digital industrial engineering • Ergonomic product and workplace design • Case studies in automotive and manufacturing sectors
	References and Textbooks
1	**Maynard's Industrial Engineering Handbook (McGraw-Hill)**
2	**Niebel, B.W.** – *Motion and Time Study* (McGraw-Hill)
3	**Khanna, O.P.** – *Industrial Engineering and Management* (Dhanpat Rai)
4	**Ralph Barnes** – *Motion and Time Study* (Wiley)
5	**Wignaraja, P.** – *Productivity Techniques* (McGraw-Hill)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5032S	
Course Title	Meta-Heuristic Optimization Techniques	

Course outcomes: On the completion of this course, the learner will able to

1. Understand the fundamentals, scope, and classification of meta-heuristic optimization methods
2. Apply GA, SA, PSO, ACO, and DE to solve engineering optimization problems
3. Analyze convergence, robustness, and performance metrics of meta-heuristic algorithms
4. Implement hybrid and advanced meta-heuristics including Memetic, Neural Network–based, and Fuzzy approaches
5. Use MATLAB and Python libraries to model and apply meta-heuristics in production and industrial engineering systems

Syllabus

1. Introduction to Meta-Heuristic Optimization

- Concept of heuristics vs meta-heuristics
- Characteristics: stochastic, population-based, iterative
- Classification: evolutionary, swarm-based, physics-based
- Applications in production and industrial engineering

2. Genetic Algorithms (GA)

- Chromosome representation and population initialization
- Fitness function design
- Selection methods: roulette wheel, tournament
- Crossover and mutation operators
- Elitism and convergence analysis
- Applications: scheduling, process parameter optimization

3. Simulated Annealing (SA) and Tabu Search

- Concept of annealing and cooling schedules

	• Acceptance probability for worse solutions • Escaping local optima • Tabu memory structure and aspiration criteria • Diversification and intensification strategies • Applications in layout design and scheduling
4.	**Swarm Intelligence Techniques** • Particle Swarm Optimization (PSO): velocity & position update • Inertia weight, learning factors, and convergence • Ant Colony Optimization (ACO): pheromone trails, probability rules • Firefly Algorithm: attractiveness and randomness • Applications in routing, logistics, and facility layout
5.	**Advanced and Hybrid Meta-Heuristics** • Differential Evolution (DE): mutation, crossover, selection • Artificial Bee Colony (ABC) algorithm • Hybrid algorithms: GA–PSO, Memetic algorithms • Integration with Neural Networks and Fuzzy Systems • Performance comparison of meta-heuristics
6.	**Applications and Implementation Tools** • Case studies in machining, assembly line balancing, logistics, and inventory • Multi-objective optimization in manufacturing systems • MATLAB toolboxes for GA, PSO, and SA • Python libraries: DEAP, PyGAD, PySwarm, Pyomo • Benchmark test functions and validation
	References and Textbooks
1	**Rao, S.S., Engineering Optimization:** *Theory and Practice, 4th Edition, Wiley*
2	**Chong, Edwin K.P., and Zak, Stanislaw H.,** *An Introduction to Optimization, 4th Edition, Wiley*
3	**Arora, Jasbir S.,** *Introduction to Optimum Design, 4th Edition, Academic Press (Elsevier)*
4	**Deb, Kalyanmoy,** *Optimization for Engineering Design: Algorithms and Examples, PHI Learning*

5	**Goldberg, David E.,** *Genetic Algorithms in Search, Optimization, and Machine Learning, Pearson Education*
6	**Simon, Dan,** *Evolutionary Optimization Algorithms, Wiley*
7	**Eiben, A.E., and Smith, J.E.,** *Introduction to Evolutionary Computing, Springer*
8	**Engelbrecht, A.P.,** *Computational Intelligence: An Introduction, Wiley*

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5033S	
Course Title	Reliability Engineering and Maintenance	

	Course outcomes: On the completion of this course, the learner will able to 1. Understand reliability concepts and probability distributions for life data 2. Apply reliability models for systems and components in manufacturing 3. Develop preventive, predictive, and condition-based maintenance strategies 4. Perform reliability testing, failure mode analysis, and risk assessment 5. Integrate reliability with quality and maintenance for industrial case studies
	Syllabus
1.	**Introduction to Reliability** • Reliability concepts and definitions • Bath-tub curve and life cycle of products • Probability models (Exponential, Weibull, Normal)
2.	**System Reliability Models** • Series, parallel, and k-out-of-n configurations • Fault tree and reliability block diagrams • Markov models for repairable systems
3.	**Reliability Testing & Analysis** • Life data analysis and hazard functions • Accelerated life testing • Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA)
4.	**Maintenance Management** • Types: Breakdown, Preventive, Predictive, TPM • Maintenance planning and scheduling • Spare parts inventory control
5.	**Condition Monitoring** • Vibration analysis, thermography, oil analysis

	• Digital maintenance systems and IoT-enabled monitoring
6.	**Case Studies & Applications** • Reliability in automotive and aerospace components • Maintenance in manufacturing plants • Risk-based maintenance practices
	References and Textbooks
1	**Srinath, L.S. –** *Reliability Engineering (East-West Press)*
2	**Charles Ebeling –** *An Introduction to Reliability and Maintainability Engineering (McGraw-Hill)*
3	**B.S. Dhillon –** *Engineering Maintenance: A Modern Approach (CRC Press)*
4	**O'Connor & Kleyner –** *Practical Reliability Engineering (Wiley)*
5	**B.S. Dhillon –** *Reliability, Quality, and Safety for Engineers (CRC Press)*

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPM5061S	
Course Title	Entrepreneurship Development	

	Course outcomes: On the completion of this course, the learner will able to 1. Demonstrate the skills and attributes required to be an entrepreneur 2. Identify problems worth solving and generate innovative business ideas 3. Analyze customer needs and develop a viable business model 4. Build a Minimum Viable Product (MVP) and validate solutions with customers 5. Apply entrepreneurial tools for financing, marketing, team-building, and venture growth
	Syllabus
1.	**Fundamentals of Entrepreneurship** • Discover yourself – entrepreneurial mindset and flow • Effectuation and entrepreneurial decision-making • Identifying entrepreneurial styles • Characteristics of successful entrepreneurs
2.	**Problem Identification and Idea Generation** • Identifying problems worth solving • Introduction to design thinking • Techniques for generating innovative ideas • Running problem interviews with potential customers • Team formation and pitching the problem
3.	**Customer Study and Value Proposition** • Customer segmentation and targeting • Identifying early adopters and adoption patterns • Defining customer personas • Crafting value propositions (using Value Proposition Canvas) • Outcome-driven innovation

4.	**Business Model and Validation** • Lean Canvas framework and business model types (B2B, B2C) • Documenting assumptions and risk identification • Developing solution demos (mock-ups, prototypes) • Conducting problem-solution validation interviews • Building an MVP and iterative development (Build–Measure–Learn loop)
5.	**Financing, Team Building, and Marketing** • Revenue streams, pricing strategies, and cost structures • Sources of venture financing and investor expectations • Importance of team building and shared leadership • Collaboration tools and techniques (Kanban, Slack, brainstorming) • Marketing and sales strategies – product positioning, channels, digital presence, social media, USP, and sales pitch
6.	**Business Operations and Regulations** • Project management for startups – planning, tracking, time management, delegation • Basics of business regulations and compliance in India • Importance of documentation and legal aspects (IP laws, contracts) • Support systems, incubators, and government schemes for entrepreneurs • Case studies of successful startups and lessons learned
	References and Textbooks
1	**Roy R.,** *Entrepreneurship*, Oxford University Press
2	**Maurya A.,** *Running Lean: Iterate from Plan A to a Plan That Works*, O'Reilly Media
3	**Jeffry A.,** *New Venture Creation*, Tata McGraw Hill
4	**Osterwalder A. and Pigneur Y.,** *Business Model Generation: A Handbook for Visionaries, Game Changers and Challengers*
5	**Gupta T.S.,** *Intellectual Property Law in India*, Kluwer Law International
6	**Saraswathi S.D.,** *Effectuation: Elements of Entrepreneurial Expertise*, Edward Elgar Publishing

7	**Kim W.C. and Mauborgne R.,** *Blue Ocean Strategy*, Harvard Business School Press
8	**Ries E.,** *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*, Crown Publishing

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5071L	
Course Title	Advanced Operations Research Laboratory	

Course outcomes: On the completion of this course, the learner will able to

1. Formulate and solve optimization problems using advanced software tools.
2. Apply OR methods to real-world industrial and production engineering scenarios.
3. Perform sensitivity analysis and interpret optimization results.
4. Model queuing and simulation systems for decision support.
5. Gain exposure to heuristic/metaheuristic optimization for complex problems

Syllabus

List of Experiments (10–12)

Introduction to Optimization Software Tools

1. Familiarization with Excel Solver / Python (PuLP, Pyomo) / MATLAB Optimization Toolbox / GAMS.
2. Solving simple LP problems.
3. Linear Programming Problem (LPP) – Production Planning
4. Formulation and solution of an LPP for maximizing profit or minimizing cost in a production system.
5. Comparison of solutions using Simplex in Solver & Python/MATLAB.

Duality & Sensitivity Analysis

6. Solve dual problems using software.
7. Conduct sensitivity analysis for changes in resources and objective coefficients.
8. Transportation & Assignment Problems
9. Solve a balanced/unbalanced transportation problem.
10. Optimize the assignment problem for workforce/job allocation.

Integer & Mixed-Integer Programming

11. The branch and bound/cutting plane method uses software.
12. Case study: Facility location or machine allocation.

Network Optimization Models

13. Shortest path, maximum flow, and minimum cost flow problems.

	14. Applications: logistics routing, project scheduling. **Nonlinear Programming (NLP)** 15. Solve constrained and unconstrained NLP problems. 16. Use MATLAB/Python to demonstrate gradient methods and penalty/barrier methods. 17. Metaheuristic Optimization (Heuristic Search) 18. Implementation of Genetic Algorithm (GA) or Simulated Annealing in MATLAB/Python. 19. Case: Job-shop scheduling or TSP (Travelling Salesman Problem). **Multi-Objective Optimization (MCDM)** 20. Solve a Goal Programming problem using Solver/Python. 21. Apply AHP/TOPSIS for a supplier selection case. **Queuing Models** 22. Simulation of M/M/1 and M/M/c queuing models. 23. Application: Service facility design in manufacturing or hospital systems. **Discrete-Event Simulation** 24. Build a small simulation model of a production line. 25. Analyze performance measures like throughput and waiting time. 26. Case Study / Mini Project (Optional, if time permits) 27. Students solve a real industrial problem (e.g., supply chain optimization, EV charging network design, workforce scheduling).
	References and Textbooks
1	Python (PuLP, Pyomo, SciPy, DEAP for GA)
2	Mathematica
3	MATLAB Optimization Toolbox / Simulink
4	GAMS / LINGO
5	Excel Solver (for fundamental problems, suitable for demo/assignments)
6	Arena / Simul8 / SimPy (for simulation experiments)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5072L	
Course Title	Industrial Engineering Laboratory	

	Course outcomes: On the completion of this course, the learner will able to 1. Conduct method study, time study, and work measurement experiments 2. Apply ergonomics principles in workplace and equipment design 3. Develop facility layout and material handling plans using analytical and software tools 4. Use productivity improvement and lean tools through experimental/mini-project work 5. Integrate safety, human factors, and digital industrial engineering concepts in lab practice
	Syllabus
1.	**Work Study and Time Measurement** • Stopwatch time study experiment • Determination of performance rating and allowances • Calculation of standard time • MOST technique
2.	**Method Study and Work Sampling** • Recording techniques: process charts, SIMO charts, two-handed process charts • Identification and elimination of ineffective motions • Designing and conducting work sampling studies
3.	**Ergonomics and Human Factors** • Measurement of anthropometric data • Ergonomic workstation and tool design • Posture analysis (RULA/REBA methods)
4.	**Facilities Planning and Material Handling** • Case study on plant layout design • Construction of relationship charts and layout planning

	• Computer-aided layout design techniques
5.	**Productivity and Lean Tools** • Productivity measurement in simulated setups • Value Stream Mapping (VSM) exercise • Application of 5S and Kaizen in lab/workshop environment
6	**Industrial Safety and Mini Project** • Laboratory/workshop safety audit • Hazard identification and risk assessment (HIRA) • Mini project / case study using integrated industrial engineering tools (e.g., line balancing, ergonomic workstation, lean improvements)
	References and Textbooks
1	**Ralph M. Barnes,** *Motion and Time Study: Design and Measurement of Work*, Wiley.
2	**ILO,** *Introduction to Work Study*, International Labour Office, Geneva.
3	**Wignjosoebroto,** *Ergonomics in Work System Design*.
4	**James A. Tompkins, John A. White et al.,** *Facilities Planning*, Wiley.
5	**Niebel, Benjamin W., and Andris Freivalds,** *Methods, Standards and Work Design*.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5073L	
Course Title	Computer Aided Analysis Laboratory	

	Course outcomes: On the completion of this course, the learner will able to 1. Understand advanced CAE workflows and their integration in product design and validation 2. Prepare and preprocess complex CAD models for finite element and multi-physics simulations 3. Perform structural, thermal, and modal analyses for real-world engineering components 4. Conduct coupled-field and non-linear simulations with optimization studies 5. Document, interpret, and present technical reports with industrial case studies
	Syllabus
1.	**Introduction to CAE and Simulation Environments** • Role of CAE in digital product development cycle • CAD–CAE–CAM integration and data exchange formats • Overview of advanced CAE tools: ANSYS Workbench, Abaqus, SolidWorks Simulation, COMSOL • Types of engineering analyses (static, dynamic, thermal, modal, coupled-field)
2.	**Preprocessing for Finite Element Analysis (FEA)** • CAD model cleanup and defeaturing for analysis • Advanced meshing: tetra, hexa, shell, solid elements; mesh refinement and convergence • Material modeling (isotropic, orthotropic, composites, nonlinear materials) • Application of complex boundary conditions and multi-load scenarios
3.	**Structural Analysis** • Static and dynamic structural analysis of industrial components (brackets, pressure vessels, machine frames) • Contact problems and nonlinear material behavior

	• Stress, strain, deformation, fatigue and fracture criteria • Post-processing: stress concentration zones, safety factor maps, failure prediction
4.	**Thermal and Modal Analysis** • Steady-state and transient thermal simulations • Heat transfer through conduction, convection, radiation, and coupled conditions • Modal analysis: natural frequencies, mode shapes, resonance identification • Harmonic and random vibration response simulations
5.	**Design Optimization and Advanced Simulations** • Parametric studies for geometry and material variations • Shape and topology optimization of mechanical parts • Multi-objective optimization with constraints (weight, stiffness, cost) • Coupled-field simulations (thermal-structural, electro-mechanical) • Introduction to AI/ML-based optimization tools in CAE
6	**Project and Technical Reporting** • Simulation-based case study on a real-life industrial component (e.g., automotive suspension arm, turbine blade, heat exchanger) • End-to-end workflow: CAD model → preprocessing → analysis → optimization → report • Preparation of a professional CAE report (model description, mesh details, boundary conditions, results, discussions, and conclusions) • Group project presentation and viva
	Software / Tools to be Used: • ANSYS Workbench (Mechanical, Thermal, Modal, Optimization) • Abaqus / COMSOL Multiphysics • SolidWorks Simulation / Autodesk Fusion 360 Simulation • MATLAB for pre/post-processing
	References and Textbooks
1	**S. Rajasekaran, G. Sankarasubramanian** *Computational Structural Mechanics* – Prentice Hall of India, 2001

2	**Saeed Moaveni** *Finite Element Analysis: Theory and Application with ANSYS* – Pearson Education.
3	**David V. Hutton** *Fundamentals of Finite Element Analysis* – Tata McGraw-Hill
4	**Robert D. Cook, David S. Malkus, Michael E. Plesha, Robert J. Witt** *Concepts and Applications of Finite Element Analysis* – Wiley
5	**Chandrupatla, T. R., & Belegundu, A. D.** *Introduction to Finite Elements in Engineering* – Prentice Hall.
6	**Daryl L. Logan** *A First Course in the Finite Element Method* – Cengage Learning
7	**Klaus-Jürgen Bathe** *Finite Element Procedures* – Prentice Hall
8	**J. N. Reddy** *An Introduction to the Finite Element Method* – McGraw-Hill
9	**P. Seshu** *Textbook of Finite Element Analysis* – PHI Learning Pvt. Ltd
10	**Ramamurthy, A.** *Computer-Aided Design and Manufacturing* – IK International
11	**Krishnamurthy, C. S.** *Finite Element Analysis: Theory and Programming* – Tata McGraw-Hill

Semester II

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5002S	
Course Title	Research Methodology and IPR	

Course outcomes: On the completion of this course, the learner will able to

1. Understand research methodologies, problem formulation, and types of research
2. Conduct literature reviews and follow ethical research practices
3. Apply data collection techniques and statistical analysis tools
4. Develop technical writing skills and present research effectively
5. Understand intellectual property rights and the patent filing process

Syllabus

1. Introduction to Research Methodology

- **Definition, Objectives, and Characteristics of Research**
- **Types of Research:**
  - Fundamental vs. Applied Research
  - Qualitative vs. Quantitative Research
  - Experimental, Analytical, and Case Study Approaches
- **Research Process and Methodology:**
  - Identifying Research Problems
  - Research Design and Approach
  - Hypothesis Formulation and Testing
  - Developing a Research Plan

2. Literature Review and Research Ethics

- **Importance and Sources of Literature Review**
  - Books, Journals, Patents, Conferences, Online Repositories
  - Systematic Literature Review (SLR) and Meta-Analysis
- **Citation and Referencing Techniques:**
  - APA, IEEE, Chicago, and other styles
  - Reference Management Software: Mendeley, Zotero, EndNote

	• **Research Ethics & Plagiarism:**
	  o Ethical Guidelines in Research
	  o Plagiarism Types and Consequences
	  o Plagiarism Detection Software: Turnitin, iThenticate
	  o Ethical Case Studies in Research Misconduct

3.	**Research Design, Data Collection, and Analysis**
	• **Data Collection Methods:**
	  o Primary Data: Surveys, Experiments, Interviews
	  o Secondary Data: Journals, Government Reports, Databases
	  o Questionnaire Design and Sampling Techniques
	• **Data Analysis Techniques:**
	  o Descriptive and Inferential Statistics
	  o Hypothesis Testing (t-test, Chi-square, ANOVA, Regression)
	  o Factor Analysis and Correlation Techniques
	• **Research Tools and Software:**
	  o MATLAB, Minitab, SPSS, R, Python for Data Analysis

4.	**Technical Writing and Research Presentation**
	• **Research Paper Writing:**
	  o Structure of a Research Paper (Abstract, Introduction, Methodology, Results, Discussion, Conclusion)
	  o Choosing the Right Journal (SCI, Scopus, UGC-CARE)
	  o Peer Review Process & Impact Factor Understanding
	• **Thesis & Dissertation Writing:**
	  o Formatting Guidelines
	  o Common Mistakes in Thesis Writing
	• **Scientific Presentation Skills:**
	  o Preparing Effective Research Posters and PPTs
	  o Oral Presentation Techniques for Conferences & Seminars

5.	**Intellectual Property Rights (IPR) and Patent Filing**
	• **Introduction to IPR:**
	  ○ Importance of IPR in Research and Innovation
	  ○ Types of Intellectual Property:
	  ▪ Trademarks
	  ▪ Copyrights
	  ▪ Patents
	  ▪ Trademarks
	  ▪ Geographical Indications
	• **Patent System in India and Abroad:**
	  ○ Indian Patent Act 1970 & Amendments
	  ○ International Patent Laws: WIPO, TRIPS, PCT
	  ○ Patent Filing Procedure:
	  ▪ Drafting a Patent Application
	  ▪ Prior Art Search
	  ▪ Patent Prosecution & Grant Process
	• **Technology Transfer & Commercialization of Research**
	• **Case Studies on Patents & IPR Disputes**

	References and Textbooks
1	**Kothari, C. R., & Garg, G. –** *Research Methodology: Methods and Techniques*, New Age International Publishers.
2	**Creswell, J. W.** – *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, SAGE Publications.
3	**Boote, D. N., & Beile, P.** – *Scholars Before Researchers: On the Centrality of the Dissertation Literature Review*, Educational Researcher.
4	**Resnik, D. B.** – *The Ethics of Science: An Introduction*, Routledge.
5	**Montgomery, D. C.** – *Design and Analysis of Experiments*, Wiley.
6	**Gupta, S. C., & Kapoor, V. K.** – *Fundamentals of Mathematical Statistics*, Sultan Chand &

	Sons.
7	**Day, R. A., & Gastel, B.** – *How to Write and Publish a Scientific Paper*, Cambridge University Press.
8	**Alley, M.** – *The Craft of Scientific Presentations*, Springer.
9	**Bouchoux, D. E.** – *Intellectual Property: The Law of Trademarks, Copyrights, Patents, and Trade Secrets*, Cengage Learning
10	**Watal, J.** – *Intellectual Property Rights in the WTO and Developing Countries*, Oxford University Press.
11	**Narayanan, P.** – *Intellectual Property Law in India*, Eastern Law House.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5013T	
Course Title	Smart Manufacturing	

	Course outcomes: On the completion of this course, the learner will able to 1. Explain the key concepts and technologies of Industry 4.0 and Smart Manufacturing 2. Analyze the role of Digital Twin in real-time monitoring and decision-making 3. Apply AI, IoT, and Big Data for intelligent manufacturing solutions 4. Implement cybersecurity measures and secure communication in smart factories 5. Evaluate sustainable and digital supply chain strategies in Industry 4.0
	Syllabus
1.	**Introduction to Industry 4.0 and Smart Manufacturing** • Evolution of Industry 4.0 and key technologies • Cyber-Physical Systems (CPS) and Internet of Things (IoT) in manufacturing • Smart factories and digital transformation strategies
2.	**Digital Twin Technology in Manufacturing** • Concept and architecture of Digital Twin (DT) • Types of Digital Twins: Product, Process, and Performance Twins • Applications of DT in predictive maintenance and real-time monitoring
3.	**Enabling Technologies for Smart Manufacturing** • Artificial Intelligence (AI) and Machine Learning (ML) applications • Big Data Analytics and Cloud Computing for manufacturing • Augmented Reality (AR), Virtual Reality (VR), and Human-Machine Interaction
4.	**Cybersecurity and Industrial Communication** • Cybersecurity challenges in Industry 4.0 • Industrial Internet of Things (IIoT) and communication protocols • Blockchain for secure manufacturing operations

5.	**Sustainability and Smart Supply Chains** • Green and sustainable manufacturing practices • Digital supply chain management and logistics optimization • Circular economy principles in Industry 4.0
6.	**Case Studies and Future Trends** • Case studies on Industry 4.0 adoption in various industries • Future trends: Industry 5.0 and human-centric automation • Implementation challenges and roadmap for smart manufacturing
	References and Textbooks
1	**Klaus Schwab** – *The Fourth Industrial Revolution*, World Economic Forum, 2017.
2	**Alain Bernard** – *Digital Twin Driven Smart Manufacturing*, Elsevier, 2019.
3	**Christoph Jan Bartodziej** – *The Concept Industry 4.0: An Empirical Analysis of Technologies and Applications in Production Logistics*, Springer, 2017.
4	**Jay Lee, Behrad Bagheri, Hung-An Kao** – *A Cyber-Physical Systems Architecture for Industry 4.0-Based Manufacturing Systems*, Manufacturing Letters, 2015.
5	**Mikell P. Groover** – *Automation, Production Systems, and Computer-Integrated Manufacturing*, Pearson, 2018.
6	**Yingfeng Zhang, Fei Tao** – *Optimization of Digital Twin-Based Cyber-Physical Production Systems*, Springer, 2020.
7	**Andreas Gebhardt, Jan-Steffen Hötter** – *Additive Manufacturing: 3D Printing for Prototyping and Manufacturing*, Hanser, 2016.
8	**Rajkumar Buyya, Amir Vahid Dastjerdi** – *Internet of Things: Principles and Paradigms*, Morgan Kaufmann, 2016.
9	**Wolfgang Wahlster** – *Industry 4.0: The Grand Challenge for Artificial Intelligence*, Springer, 2018.
10	**Michael E. Porter, James E. Heppelmann** – *How Smart, Connected Products Are Transforming Companies*, Harvard Business Review, 2015.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** I
Course Code	PEPI5014T	
Course Title	Production and Operations Management	

Course outcomes: On the completion of this course, the learner will able to

1. Understand the fundamentals of production and operations management
2. Apply forecasting, capacity planning, and scheduling techniques for efficient production
3. Analyze inventory management strategies and material planning systems
4. Implement quality control, lean principles, and continuous improvement techniques
5. Evaluate facility location and layout strategies for optimized operations

Syllabus

1. Introduction to Production and Operations Management

- Scope and importance of Production & Operations Management (POM)
- Differences between manufacturing and service operations
- Production systems and process selection
- Key performance indicators in operations

2. Forecasting and Demand Planning

- Importance of forecasting in production planning
- Qualitative and quantitative forecasting techniques
- Time series analysis, regression models, and moving averages
- Demand management and capacity planning

3. Facility Location and Layout

- Factors influencing facility location decisions
- Types of plant layouts – Product, Process, Cellular, Fixed Position
- Assembly line balancing and optimization

4. Capacity Planning and Production Scheduling

- Types of capacity and capacity measurement

	• Aggregate planning and master production scheduling (MPS) • Scheduling techniques – Gantt charts, Johnson's Rule • Sequencing of operations and Just-in-Time (JIT) manufacturing
5.	**Inventory Management and Materials Requirement Planning (MRP)** • Functions and types of inventory • Economic Order Quantity (EOQ), ABC analysis, and safety stock determination • Material Requirement Planning (MRP) and Manufacturing Resource Planning (MRP II) • Enterprise Resource Planning (ERP) in production
6.	**Quality Management and Lean Manufacturing** • Total Quality Management (TQM) and Six Sigma principles • Statistical Process Control (SPC) and Process Capability Index (Cp, Cpk) • Lean Manufacturing: 5S, Kaizen, Kanban, Value Stream Mapping (VSM) • ISO standards and Quality certification processes
	References and Textbooks
1	**Chase, R. B., Shankar, R., & Jacobs, F. R.** – *Operations and Supply Chain Management*, McGraw-Hill, 15th Edition
2	**Stevenson, W. J.** – *Operations Management*, McGraw-Hill, 13th Edition
3	**Heizer, J., Render, B., & Munson, C.** – *Operations Management: Sustainability and Supply Chain Management*, Pearson, 12th Edition
4	**Slack, N., Brandon-Jones, A., & Johnston, R.** – *Operations Management*, Pearson, 9th Edition
5	**Krajewski, L. J., Ritzman, L. P., & Malhotra, M. K.** – *Operations Management: Processes and Supply Chains*, Pearson, 12th Edition
6	**Schroeder, R. G., Goldstein, S. M., & Rungtusanatham, M.** – *Operations Management: Contemporary Concepts and Cases*, McGraw-Hill, 6th Edition
7	**Jayaraman, I., & Sridharan, R.** – *Production and Operations Management*, Laxmi Publications, 2nd Edition

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5041S	
Course Title	Robotics in Manufacturing	

	Course outcomes: On the completion of this course, the learner will able to 1. Understand fundamentals of robotics and their applications in manufacturing 2. Model robot kinematics and dynamics 3. Apply sensors and control systems for robotic operations 4. Integrate robotics in flexible manufacturing systems 5. Use simulation software for robot programming
	Syllabus
1.	**Introduction to Robotics** • Types of robots, classification, and industrial applications • End-effectors and actuators
2.	**Robot Kinematics & Dynamics** • Forward and inverse kinematics • Jacobians and singularities • Dynamics of manipulators
3.	**Robot Control Systems** • Feedback control, trajectory planning • Adaptive and intelligent control
4.	**Sensing & Machine Vision** • Proximity, force, tactile, and vision sensors • Machine vision systems and applications
5.	**Robotics in Manufacturing** • Material handling, welding, machining, assembly • Robotics in additive manufacturing and Industry 4.0
6.	**Simulation & Case Studies** • Robot programming and simulation (RoboDK, ABB RobotStudio) • Applications in automotive and electronics industries

	References and Textbooks
1	**Groover, M.P.** – *Industrial Robotics: Technology, Programming and Applications* (McGraw-Hill)
2	**Craig, J.J.** – *Introduction to Robotics: Mechanics and Control* (Pearson)
3	**Spong, M.W.** – *Robot Modeling and Control* (Wiley)
4	**Fu, Gonzalez & Lee** – *Robotics: Control, Sensing, Vision and Intelligence* (McGraw-Hill)
5	**Niku, S.B.** – *Introduction to Robotics* (Pearson)

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5042S	
Course Title	Product Lifecycle Management (PLM)	

	Course outcomes: On the completion of this course, the learner will able to 1. Understand the fundamentals, scope, and benefits of Product Lifecycle Management in industry 2. Analyze various phases of the product lifecycle and their integration with PLM 3. Explain PLM system architecture, Product Data Management, and integration with CAD/CAM/ERP 4. Evaluate PLM implementation strategies, collaboration practices, and organizational challenges 5. Explore PLM tools, industrial applications, and emerging trends including Digital Twin and Industry 4.0
	Syllabus
1.	**Fundamentals of PLM** • Definition, scope, and history of PLM • Benefits and strategic role in modern industries • Relationship between PLM, PDM, and ERP • Key stakeholders across the lifecycle
2.	**Product Lifecycle Phases and Integration** • Phases: ideation, design, manufacturing, sales, service, disposal • Integration of PLM with lifecycle phases • Case study: lifecycle of a consumer product (e.g., smartphone, automobile)
3.	**PLM Architecture and PDM** • PLM system architecture • Metadata and configuration control • CAD/CAM/CAE integration • Workflow and change management • PDM fundamentals: document control, versioning, BOM, access control

	• PLM vs. PDM comparison
4.	**PLM Strategy, Implementation, and Collaboration** • Roadmap development and pilot projects • Implementation challenges: organizational and cultural • Concurrent engineering and collaborative design • Cloud-based PLM and supply chain integration • Real-time data access in PLM
5.	**PLM Tools and Software Platforms** • Siemens Teamcenter, PTC Windchill, Dassault ENOVIA, Autodesk Fusion Lifecycle • Features and demonstrations (case videos) • Criteria for PLM software selection • Deployment and integration planning
6.	**Industry Applications and Emerging Trends** • Applications in automotive, aerospace, electronics, pharmaceuticals • Sustainable product design and innovation integration • Recent trends: AI, ML, IoT, and Industry 4.0 in PLM • Agile product development and additive manufacturing • Open-source PLM solutions
	References and Textbooks
1	**Michael Grieves,** *Product Lifecycle Management: Driving the Next Generation of Lean Thinking*
2	**John Stark,** *Product Lifecycle Management in the Digital Twin Era*, Springer, 2020
3	**Antti Saaksvuori and Anselmi Immonen,** *Product Data Management*, Springer
4	**Patrick Hillberg,** *Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation*, Independently published
5	**Uthayan Elangovan,** *Digital Manufacturing & Product Lifecycle Management (PLM), Notion Press*

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5043S	
Course Title	Autonomous Systems and Industry 5.0	

	Course outcomes: On the completion of this course, the learner will able to 1. Explain the principles and architecture of autonomous systems in industrial contexts 2. Apply AI, robotics, and machine learning for autonomous decision-making 3. Evaluate human–machine collaboration and ergonomics in Industry 5.0 systems 4. Analyze ethical, safety, and sustainability aspects of autonomy in manufacturing 5. Integrate autonomous solutions for logistics, production, and service industries
	Syllabus
1.	**Introduction to Industry 5.0 and Autonomous Systems** • Evolution from Industry 4.0 to Industry 5.0: human-centric, sustainable, resilient • Characteristics of autonomous systems (self-perception, decision-making, adaptation) • Comparison: Smart Manufacturing (I4.0) vs Human-Centric Autonomy (I5.0) • Case studies of early Industry 5.0 applications
2.	**Fundamentals of Autonomous Systems** • Components: sensors, actuators, controllers, AI modules • Levels of autonomy in industrial systems • Perception, planning, and control frameworks • Autonomous vehicles, drones, cobots, AGVs in production & logistics
3.	**AI and Robotics for Autonomy** • Machine learning and reinforcement learning for autonomy • Computer vision and object recognition in robotic tasks • Collaborative robotics (cobots) for human–machine teamwork • Path planning, adaptive control, and real-time decision-making
4.	**Human–Machine Collaboration and Ergonomics** • Principles of human–robot interaction (HRI) • Ergonomics and cognitive load in Industry 5.0 workplaces • Trust, acceptance, and ethics in autonomous decision-making

	• Workplace safety standards for autonomous systems
5.	**Applications in Industry 5.0** • Autonomous logistics and warehouses • Predictive maintenance using autonomy • Healthcare, service robotics, and social robots • Sustainability through resource-efficient autonomous operations
6.	**Future Directions and Challenges** • Resilient manufacturing and adaptive systems • Swarm robotics and distributed autonomous decision-making • Integration of bio-inspired autonomy and edge AI • Policy, regulation, and ethical governance of autonomy
	References and Textbooks
1	**Hamid R. Arabnia,** *Autonomous Systems and Intelligent Agents in Industry*.
2	**Bruno Siciliano & Lorenzo Sciavicco,** *Robotics: Modelling, Planning and Control*.
3	**Ovidiu Vermesan & Peter Friess,** *Digitising Industry – Towards Industry 5.0*.
4	**Kim J. Vicente,** *Human-Tech: Designing Human-Centered Technology*.
5	Recent IEEE Transactions on *Automation Science and Engineering*, *Robotics*, and *Human–Machine Systems*.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5051S	
Course Title	Circular Manufacturing and Sustainability	

	Course outcomes: On the completion of this course, the learner will able to 1. Understand principles of circular economy in manufacturing 2. Apply sustainable product design and material reuse strategies 3. Analyze waste reduction and recycling in industrial processes 4. Implement eco-design and life cycle assessment (LCA) 5. Evaluate industrial case studies in circular manufacturing
	Syllabus
1.	**Introduction to Circular Manufacturing and Circular Economy** • Linear vs circular models • Circular business models
2.	**Sustainable Product Design** • Design for disassembly, reuse, and recycling • Eco-design principles
3.	**Circular Supply Chains** • Reverse logistics and remanufacturing • Closed-loop manufacturing
4.	**Tools and Methodologies** • Life Cycle Assessment (LCA) • Material flow analysis
5.	**Case Studies & Applications** • Circularity in automotive, electronics, packaging • Policy and standards in sustainable manufacturing
	References and Textbooks
1	**Webster, K. The Circular Economy:** *A Wealth of Flows, Ellen MacArthur Foundation*
2	**Lacy, P., & Rutqvist, J.** *Waste to Wealth: The Circular Economy Advantage, Palgrave*

	Macmillan
3	**Stahel, W. R.,** *The Circular Economy: A User's Guide, Routledge*
4	**Kirchherr, J., & Reike, D.,** Research *on the Circular Economy: A Systematic Literature Review, Elsevier*
5	**Sharma, S.,** *Circular Economy in Manufacturing: Practices and Challenges, Springer*

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5052S	
Course Title	Energy Management in Industries	

Course outcomes: On the completion of this course, the learner will able to

1. Understand the importance of energy conservation and management in industrial systems
2. Analyze energy consumption patterns and identify opportunities for energy efficiency
3. Apply techniques for energy auditing, monitoring, and performance evaluation
4. Explore renewable and alternative energy options for industrial applications
5. Evaluate case studies and best practices of energy management in manufacturing industries

Syllabus

1. Fundamentals of Energy Management

- Importance of energy management in industries
- Concepts of energy efficiency and conservation
- Role of energy manager and energy policy in organizations
- Standards and regulatory frameworks

2. Energy Auditing and Monitoring

- Types of energy audits: preliminary, detailed
- Energy audit methodology and reporting
- Instruments for energy measurement and monitoring

Key Performance Indicators (KPIs) of energy efficiency

3. Energy Efficiency in Industrial Systems

- Energy use in boilers, furnaces, steam systems
- Motors, pumps, compressors, fans, and HVAC systems
- Lighting systems and power distribution
- Waste heat recovery techniques

4. Renewable and Alternative Energy in Industries

- Solar thermal and photovoltaic systems

	• Biomass energy and biogas utilization • Wind energy applications • Cogeneration and trigeneration systems
5.	**Energy Management Techniques and Tools** • Demand-side management and load optimization • Energy-efficient technologies and retrofitting • Process integration and pinch analysis • Life Cycle Costing (LCC) and payback period analysis
6.	**Case Studies and Industrial Applications** • Energy efficiency in steel, cement, textile, and chemical industries • ISO 50001 energy management systems • Benchmarking and best practices • Future trends: Smart grids, AI, and IoT for energy management
	References and Textbooks
1	**W. R. Murphy and G. McKay,** *Energy Management, Butterworth-Heinemann*
2	Guidebook for National Certification Examination for Energy Managers and Energy Auditors, Bureau of Energy Efficiency (BEE), Govt. of India
3	**Barney L. Capehart, Wayne C. Turner, and William J. Kennedy,** *Guide to Energy Management, Fairmont Press*
4	**S. C. Tripathy,** *Electric Energy Utilization and Conservation, Tata McGraw-Hill*
5	**Y.P. Abbi and Shashank Jain,** *Handbook on Energy Audit and Environment Management, TERI*
6	**F. Kreith and D.Y. Goswami,** *Energy Management and Conservation Handbook, CRC Press*
7	**Albert Thumann,** *Handbook of Energy Audits, Fairmont Press*

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5053S	
Course Title	Economics, Finance, Accounting and Costing	

	Course outcomes: On the completion of this course, the learner will able to 1. Apply the principles of engineering economics to evaluate industrial projects 2. Analyze financial statements and assess organizational performance 3. Apply costing methods for effective production and process cost management 4. Integrate financial and cost accounting principles for managerial decision-making 5. Develop strategies for cost control, budgeting, and financial planning in industries
	Syllabus
1.	**Engineering Economics** • Basic concepts of economics relevant to engineers • Demand, supply, elasticity, and market equilibrium • Time value of money, present worth and future worth analysis • Break-even analysis and sensitivity analysis
2.	**Financial Management** • Introduction to finance functions in industries • Capital structure and cost of capital • Working capital management • Capital budgeting techniques (NPV, IRR, Payback, etc.)
3.	**Accounting Principles** • Basics of accounting: Journal, ledger, trial balance • Balance sheet, Profit & Loss account, Cash flow statement • Ratio analysis for performance evaluation • Depreciation methods
4.	**Costing Methods** • Elements of cost: material, labor, overheads • Job costing, process costing, activity-based costing • Standard costing and variance analysis

	• Marginal costing and decision-making
5.	**Budgeting and Control** • Types of budgets (flexible, zero-based, performance-based) • Budgetary control and responsibility accounting • Cost control and reduction techniques • Internal audit and financial control in industries
6.	**Industrial Applications** • Cost-benefit analysis of industrial projects • Case studies on manufacturing cost optimization • Financial decision-making in production planning • Integration of costing and accounting with ERP/PLM systems
	References and Textbooks
1	**Prasanna Chandra,** *Financial Management – Theory and Practice*, Tata McGraw Hill.
2	**M.Y. Khan & P.K. Jain,** *Financial Management*, McGraw Hill.
3	**S.P. Jain & K.L. Narang,** *Cost Accounting*, Kalyani Publishers.
4	**I.M. Pandey,** *Essentials of Financial Management*, Vikas Publishing.
5	**Horngren C.T.,** *Cost Accounting: A Managerial Emphasis*, Pearson.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5062S	
Course Title	Industrial Safety, Health, and Risk Assessment	

	Course outcomes: On the completion of this course, the learner will able to 1. Understand safety concepts, accident causation, and prevention methods in industries 2. Apply occupational health and ergonomics principles to improve workplace safety 3. Identify, analyze, and assess industrial hazards and associated risks 4. Implement safety management systems, standards, and statutory regulations 5. Develop risk mitigation and emergency preparedness strategies for industries
	Syllabus
1.	**Introduction to Industrial Safety** • Importance of safety in industries • Accident causation theories and accident statistics • Principles of accident prevention • Safety culture and behavior-based safety
2.	**Occupational Health and Hygiene** • Occupational diseases and health hazards • Industrial hygiene: air quality, noise, vibration, radiation • Ergonomics and human factors in safety • Workplace monitoring and exposure limits
3.	**Hazard Identification and Risk Assessment** • Types of hazards: physical, chemical, mechanical, electrical, fire and explosion • Hazard identification techniques (checklists, HAZOP, FMEA) • Risk assessment and risk matrix • Quantitative risk assessment methods
4.	**Safety Management Systems** • Safety policies, objectives, and planning • OHSAS/ISO 45001 framework • Safety audit and performance measurement

	• Role of leadership and training in safety
5.	**Legal and Statutory Provisions** • Indian Factories Act, 1948 • Occupational Safety, Health and Working Conditions Code, 2020 • Environmental laws relevant to safety (Air Act, Water Act, EPA) • International standards and guidelines (ILO, OSHA)
6.	**Emergency Preparedness and Case Studies** • Emergency planning and disaster management • Fire safety and explosion prevention • Case studies of industrial accidents (Bhopal gas tragedy, Chernobyl, etc.) • Learning lessons and best practices
	References and Textbooks
1	**R.K. Jain and Sunil S. Rao,** *Industrial Safety, Health and Environment Management Systems*, Khanna Publishers.
2	**D.A. Crowl and J.F. Louvar,** *Chemical Process Safety – Fundamentals with Applications*, Pearson.
3	**Frank P. Lees,** *Loss Prevention in Process Industries*, Elsevier.
4	**Hughes P. and Ferrett E.,** *Introduction to Health and Safety at Work*, Routledge.
5	**Goetsch D.L.,** *Occupational Safety and Health for Technologists, Engineers and Managers*, Pearson.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5074L	
Course Title	Advanced Manufacturing Laboratory	

Course outcomes: On the completion of this course, the learner will able to

1. Operate and program CNC milling machines for precision machining
2. Perform welding processes using laser, MIG (robotic), and TIG technologies
3. Analyze the effect of process parameters on weld quality and machining performance
4. Interpret microstructural and mechanical properties of weldments
5. Integrate automation and robotics in advanced manufacturing processes

Syllabus

1. CNC Milling

- Introduction to CNC milling machine, safety precautions.
- Basic programming (G-codes, M-codes).
- Milling of a component with slotting, facing, and contouring.
- Study of surface roughness and dimensional accuracy.

2. Laser Welding

- Introduction to laser welding process and safety practices.
- Demonstration of bead-on-plate welding with parameter variation.
- Analysis of weld penetration and heat-affected zone (HAZ).
- Macro and micro examination of weld cross-section.

3. Robotic MIG Welding

- Familiarization with robotic welding cell (programming & path teaching).
- Execution of MIG welding on mild steel specimens.
- Effect of current, voltage, and speed on weld bead geometry.
- Comparison of robotic vs manual welding.

4. TIG Welding

- Setup and safety in TIG welding operations.
- Welding of thin stainless steel and aluminum sheets.
- Effect of shielding gas flow rate on weld quality.

	• Visual inspection and NDT of welds.
5.	**Quality Evaluation of Welds** • Destructive and non-destructive testing of welds (macro-etching, hardness). • Metallographic preparation of welded joints. • Correlation between process parameters and defects (porosity, cracks).
6.	**Mini Project / Case Study** • Design and fabrication of a simple welded component integrating CNC machining and welding. • Comparative study of different welding processes for the same material. • Report preparation with results, analysis, and conclusions.
	References and Textbooks
1	**Mikell P. Groover –** *Fundamentals of Modern Manufacturing*.
2	**J. Lawrence –** *Advances in Laser Materials Processing*.
3	**John A. Schey –** *Processes, Materials, and Manufacturing*.
4	**Cary, Howard B. –** *Modern Welding Technology*.
5	Selected IEEE / Elsevier Journals on *Advanced Manufacturing & Welding Automation*.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5075L	
Course Title	Product Lifecycle Management Laboratory	

Course Outcomes:

1. On the completion of this course, the learner will be able to:
2. Understand the Siemens Teamcenter interface and manage product items, datasets, and revisions
3. Create and modify multi-level product structures and Bill of Materials (BOM) using Structure Manager
4. Apply version control, lifecycle transitions, and workflow processes for product data management
5. Execute engineering change management tasks including change request and approval workflows
6. Demonstrate collaborative product development and access control within a PLM environment

	List of Experiments/Assignments
1.	Introduction to Siemens Teamcenter interface, modules, and navigation
2.	Creation of items and datasets, understanding Item Master and revisions
3.	Creating and managing multi-level Bill of Materials (BOM) using Structure Manager
4.	Lifecycle status changes (e.g., Released, In-Work, Obsolete) and workflow demonstration
5.	Document and version control: managing CAD and non-CAD files in Teamcenter
6.	User roles, access control, and privilege settings in Teamcenter
7.	Engineering Change Management: initiating and processing Change Request and Change Notice
8.	Workflow automation: triggering review and approval processes using Workflow Designer
9.	Teamcenter-CAD integration: managing Solid Edge/NX files within Teamcenter (if integration available)
10.	Digital mock-up and visualization using Teamcenter Visualization

11.	Mini project: managing the digital lifecycle of a sample product assembly from concept to release (e.g., fan, fixture, bracket)
	References and Text Books
1	Michael Grieves, Product Lifecycle Management: Driving the Next Generation of Lean Thinking
2	John Stark, Product Lifecycle Management
3	Saaksvuori and Immonen, Product Lifecycle Management: 21st Century Paradigm for Product Realisation
4	John Stark, Product Lifecycle Management in the Digital Twin Era, Springer, 2020
5	Antti Saaksvuori and Anselmi Immonen, Product Data Management, Springer
6	Patrick Hillberg, Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation, Independently published
7	Uthayan Elangovan, Digital Manufacturing & Product Lifecycle Management (PLM), Notion Press

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** II
Course Code	PEPI5076L	
Course Title	Manufacturing Processes Simulation Laboratory	

Course outcomes: On the completion of this course, the learner will able to

1. Simulate and analyze CNC machining processes using **GVCNC**
2. Evaluate casting performance (flow, solidification, and stress) using **Z-CAST PRO Stress**
3. Model and predict metal flow, load, strain, and temperature in forming processes using **AFDEX**
4. Optimize process parameters for defect minimization and improved part quality
5. Correlate virtual simulation results with real-world manufacturing behavior

Syllabus

List of Experiments (Any 8)

A. CNC Simulation (Using GVCNC)

1. Introduction to CNC Machining Simulation
   – Interface, toolpath generation, and virtual machining environment.
   – Part program creation for turning and milling operations.
2. Simulation of CNC Turning Operations
   – Simulation of facing, turning, and taper operations; toolpath and material removal visualization.
3. Simulation of CNC Milling Operations
   – Toolpath simulation for pocket milling and contouring; chip load and machining time estimation.
4. Toolpath Optimization and Error Analysis
   – Comparison of conventional vs climb milling strategies; tool collision and overcut detection.

B. Casting Simulation (Using Z-CAST PRO Stress)

5. Flow Simulation in Sand Casting
   – Mold filling analysis, flow front tracking, air entrapment prediction.
6. Solidification and Shrinkage Simulation
   – Prediction of hot spots, porosity zones, and microstructural effects.

	7. Thermal-Stress and Distortion Analysis – Simulate residual stress and distortion during cooling; suggest design modifications for defect control. **C. Metal Forming Simulation (Using AFDEX)** 8. Simulation of Open and Closed Die Forging – Material flow, die load estimation, and flash formation visualization. 9. Simulation of Sheet Metal Deep Drawing Process – Study of blank holder force, wrinkling, and thinning; prediction of cup geometry. 10. Extrusion or Rolling Process Simulation – Analyze strain distribution, die pressure, and defect formation in extrusion/rolling. ***(Optional Advanced Experiment)*** 11. Optimization of Metal Forming Parameters – DOE or Taguchi-based parameter optimization using AFDEX outputs (load, temperature, strain).
	References and Textbooks
1	Rao, P.N., *Manufacturing Technology*, Vol. 1 & 2, Tata McGraw-Hill.
2	Kalpakjian & Schmid, *Manufacturing Engineering and Technology*, Pearson.
3	Groover, M.P., *Fundamentals of Modern Manufacturing*, Wiley.
4	AFDEX, Z-CAST PRO, and GVCNC User Manuals.
5	Journal papers on manufacturing process simulation and optimization.

Semester III

Self-Learning Course – I

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** III
Course Code	PEPI5101S	
Course Title	Micro and Nano Manufacturing Systems	

Focus: Advanced precision manufacturing at micro/nano scales.

Brief Syllabus:

- **Module 1:** Principles of micro-machining, micro-EDM, micro-USM, and laser micro-processing.
- **Module 2:** Lithography-based microfabrication, MEMS fabrication techniques, and surface functionalization.
- **Module 3:** Metrology for micro/nano components using SEM, AFM, and optical profilometry.
- **Module 4:** Applications in biomedical devices, micro-fluidics, and precision optics.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** III
Course Code	PEPI5102S	
Course Title	Sustainable Remanufacturing & E-Waste Management	

Focus: Circular economy practices applied specifically to end-of-life electronic and mechanical products.

Brief Syllabus:

- **Module 1:** Remanufacturing frameworks, core collection strategies, and disassembly planning.
- **Module 2:** E-waste processing methods, precious metal recovery, and hazardous material handling.
- **Module 3:** Design for Remanufacturing (DfR) and product health monitoring techniques.
- **Module 4:** Regulatory standards, Extended Producer Responsibility (EPR), and circular business models.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** III
Course Code	PEPI5103S	
Course Title	Machine Tool Metrology and Calibration	

Focus: Precision measurements and machine tool performance verification

Brief Syllabus:

- **Module 1:** Geometric Error Analysis in CNC machine tools, alignment testing, and pitch/yaw errors.
- **Module 2:** Laser Interferometry and Ballbar testing for dynamic machine accuracy assessment.
- **Module 3:** Coordinate Measuring Machine (CMM) programming, touch probes, and surface metrology.
- **Module 4:** ISO 230 standards for machine tool evaluation and thermal error compensation.

Self-Learning Course – II

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** III
Course Code	PEPI5201S	
Course Title	Design Thinking and Systematic Innovation (TRIZ)	

Focus: Problem-solving methodologies for engineering design and process optimization.

Brief Syllabus:

- **Module 1:** Design Thinking methodology: Empathize, Define, Ideate, Prototype, Test.
- **Module 2:** Fundamentals of TRIZ (Theory of Inventive Problem Solving) and Contradiction Matrix.
- **Module 3:** 40 Inventive Principles applied to mechanical and production engineering problems.
- **Module 4:** Su-Field analysis, Substance-Field modeling, and patentable solution generation.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** III
Course Code	PEPI5202S	
Course Title	Six Sigma DMAIC Methodology	

Focus: Continuous improvement and quality enhancement protocols for shop-floor processes.

Brief Syllabus:

- **Module 1:** Define & Measure: Project charter, SIPOC diagram, Process Mapping, and Measurement System Analysis (Gage R&R).
- **Module 2:** Analyze: Root Cause Analysis, Pareto charts, Fishbone diagrams, and Hypothesis Testing.
- **Module 3:** Improve: Design of experiments basics, Kaizen implementation, and solution selection matrices.
- **Module 4:** Control: Control plans, Statistical Process Control (SPC) charts, and standard operating procedure (SOP) documentation.

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** III
Course Code	PEPI5203S	
Course Title	Human Factors & Cognitive Ergonomics in Smart Workplaces	

Focus: Optimizing human-technology interaction in automated and Industry 5.0 environments.

Brief Syllabus:

- **Module 1:** Cognitive ergonomics principles, mental workload assessment (NASA-TLX), and situational awareness.
- **Module 2:** Human-Machine Interface (HMI) design for control rooms, smart screens, and AR headsets.
- **Module 3:** Ergonomics in Human-Robot Collaboration (Cobots) and safety zone design.
- **Module 4:** Occupational health metrics, stress evaluation, and human error risk reduction strategies.

Mandatory Non-Credit Course

Programme	M. Tech. (Production & Industrial Engineering)	**Semester -** III
Course Code	PEPM5301S	
Course Title	Effective Business Communication (MNC)	

About Course

In a business scenario, communication includes written letters, summaries, and emails. Clear communication skills are needed for impactful oral presentations in front of an audience. Even everyday practices like participating in meetings and managing interpersonal communication are key to achieving long and short-term business goals.

Course Content

- The Process of Communication
- Professional Writing - The Basics and applications
- Presentations
- Interpersonal Skills