M.Tech. in Manufacturing and Materials Engineering

Total credit requirement for the course completion: minimum **128 credits**
IC: Institute core = **64 credits**, PC:
Program core= **52 credits**,
PE: Program
Electives = 12

credits 1st semester:

- 6 core courses = 31 credits prescribed program core (4 theory courses with 6 credits each, one core lab with 5 credits + Research Methodology with 2 credits)

2nd semester:

- 2 Core courses (6 credits each) = 12 credits prescribed program core
- 2 Elective courses (6 credits each)
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- Seminar (4 credits)

3rd semester:

- MTech Technical Project work - Phase I (32 credits)

4th semester:

- MTech Technical Project work - Phase II (32 credits)

Semester-I 31 Credits

Course Name	L-T-P-C	Objective of the course	Category
Fundamentals of Casting and Welding (New)	3-0-0-6	To introduce and orient students to the concepts of solidification, casting and weld design, advancement in casting and welding.	PC
Physical and Mechanical Metallurgy (New)	3-0-0-6	To understand relationships between composition, processing, microstructure, and physical and mechanical properties, behavior of metals and alloys subjected to applied forces	PC
CNC and Additive Manufacturing (New)	3-0-0-6	To introduce computer numerical and mathematical concepts, additive manufacturing design and concepts.	PC
Engineering Mathematics for Advanced Studies (ME 903)	3-0-0-6	To make the mathematical foundations	PC
Introduction to Programming and Modeling Laboratory (ME 621)	1-0-3-5	To introduce students to programming, analysis tools and software, Operating systems, R and Python programming, etc.	PC
Research Methodology (New)	0-0-3-2	To introduce students to literature review, report preparations and seminar presentation to a large audience as seminar on research topics in Mechanical Engineering	PC

1	**Title of the course** (L-T-P-C)	**Fundamentals of Casting Welding** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Casting:** Introduction; Classification of casting processes; Advantages and drawbacks; Historical background; Foundry practice on video; Casting of BMW car wheels on video; Patterns; Shrinkage and Mechanical allowances; Moulds; Gating system; Properties of moulding sand; Gating design; Vertical gating: aspiration effect; Optimum riser design. Solidification of pure metal and alloy; Solidification time: Chvorinov's rule; Categories of metal casting processes; Steps in sand casting; Mould properties and characteristics; Shell moulding; Investment casting: Process characteristics, Process to show through video, Advantages and disadvantages; Multiple mould casting, Steps in permanent mould casting; Die casting: Hot and Cold Chamber die casting; Centrifugal casting; Continuous casting; Cost analysis of casting; Casting defects; Product design considerations in casting; **Welding Processes:** Preamble, classification of joining processes; Welding: advantages and limitations; Joints in welding; Fusion welding processes; Heat density; Comparison among welding processes; Features of a Fusion Welded Joint; Typical Fusion Welded Joints; Heat Affected Zone; Solidification of Weld; Solid-State (Phase) Welding: Forge welding, butt welding, friction welding, explosion welding, resistance welding. Ultrasonic welding process characteristics and applications; Electron beam welding; Laser beam welding; Plasma arc welding; Arc welding: characteristics; Consumable and non-consumable electrodes; Power source; Shielded metal arc welding: Principles and applications; Gas metal arc welding; Gas Tungsten Arc Welding; Tungsten-Inert Gas Welding (TIG); Submerged Arc Welding; Gas Welding: Principles, types of flames; Brazing and Soldering: Process capabilities; Welding defects
4	**Texts/References**	1. A.Ghosh and Asok Mallik - Manufacturing Science, 2nd Edition, East-West Press Pvt Ltd, Year 2010. 2. G.K.Lal and S.K.Choudhury - Fundamental of Manufacturing Processes Alpha Science International, 2005 3. Richard Flinn - Fundamentals of Metal Casting, Addison-Wesley Publishing Co., Inc., 1963. 4. Kalpakjian and Schmid - Manufacturing Processes for Engineering 5. Materials, 2nd Edition Pearson Education 2010

1	**Title of the course** (L-T-P-C)	**Physical and Mechanical Metallurgy** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Module 1:** Structure of Metals, Unit Cells, Crystal structure of metals, Coordination Number 7 1.9 Anisotropy, Textures or Preferred Orientations, Miller Indices, The Stereographic Projection, Structure of Alloys, Imperfections in Crystals, Different Characterization Techniques: XRay Diffraction, Electron Microscopy **Module 2:** Phase Diagrams, Phase Rule, Binary Phase Diagram, Microstructural Changes during cooling, Fe-C Equilibrium diagram, Effect of alloying element on Fe-C diagram, Ternary and Quaternary Phase diagram, Phase transformations, diffusion in solids, Nucleation and growth Kinetics, Solidification, Examples of phase transformation, Precipitation and Age hardening, Recovery, Recrystallization and grain growth, Heat Treatment of Steels, T-T-T, C-C-T diagram **Module 3:** Stress and Strain Relationships for Elastic Behavior: Stress state, Mohr's Circle, stress tensor, strain at a point, Hydrostatic and Deviatoric stress, Hooke's law, Strain Energy, Anisotropy, True stress and True Strain, Yield Criteria and Locus, Yield Anisotropy, Plastic Stress-Strain relations **Module 4:** Dislocation Mediated Plasticity, Critical Resolved Shear Stress, Deformation of Cubic Crystals, Deformation Twinning, Strain Hardening of Single Crystals, Observation of Dislocations, Dislocation Characteristics, Stress Fields and Energies of Dislocations, Forces on Dislocations, Cross-slip and climb, Frank-Read source, Dislocation Interactions, Slip Systems, Dislocation density and Stress, grain boundary **Module 5:** Strengthening Mechanisms: Grain Boundaries Strengthening, Strain Hardening, Solid-Solution Strengthening, Precipitation Strengthening, Dispersion Hardening, Introduction to Fracture in Metals, Theoretical Cohesive Strength of Metals, Griffith Theory of Brittle Fracture, Fractography, Dislocation Theories of Brittle Fracture, Ductile Fracture **Module 6:** Materials Testing and Mechanical Properties: Tension Test, Hardness Test, Torsion Test, Fracture Mechanics, Fatigue of Metals, Creep and Stress Rupture, Brittle Fracture and Impact Testing, Fundamentals of Metalworking: forgoing, rolling, extrusion, sheet-metals, Machining, Ferrous and Nonferrous Engineering alloys
4	**Texts/References**	1. Materials Science and Engineering: A First Course by V. Raghavan 2. Physical Metallurgy Principles by Robert E. Reed-Hill 3. Mechanical Metallurgy by George E. Dieter 4. Materials Science and Engineering: An Introduction by William D. Callister 5. Physical Metallurgy Principles and Practice by V. Raghavan.

1	**Title of the course** (L-T-P-C)	**CNC and Additive Manufacturing** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	• Introduction to Computer Numerical Control (NC/CNC), CNC machines, Industrial applications of CNC, and economic benefits of CNC. CNC Machine Tools, CNC tooling: Qualified and pre-set tooling, tooling systems, tool sets, automatic tool changers, work holding, and setting. Programming: Part programming language, programming procedures, proving part programs, computer-aided part programming. Geometry code (G-Code). • Introduction to Additive Manufacturing (AM): Overview of Additive Manufacturing (AM), AM technologies, classification of AM processes: Sheet Lamination, Material Extrusion, Photo- polymerization, Powder Bed Fusion, Binder Jetting, and Direct Energy Deposition, Popular AM processes. Additive manufacturing of different materials. Metal Additive Manufacturing, Reverse Engineering. • Design for additive manufacturing, Path planning, STL file processing, • Materials for Additive Manufacturing, • Characterization of Additive Manufacturing • Large scale Additive manufacturing, • Case studies of Additive Manufacturing and Integration of hybrid manufacturing technologies.
4	**Texts/References**	1. Gibson, D. W. Rosen, and B. Stucker, Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing. Springer, 2014. 2. C. K. Chua and K. F. Leong, Rapid Prototyping: Principles and Applications in Manufacturing. World Scientific, 2003. 3. Ibrahim Zaid, R. Sivasubramanian, CAD/CAM: Theory and Practice. McGraw Hill Education,2nd edition, 2009. 4. M. P. Groover, E. W. Zimmers, CAD/CAM: Computer-aided design and manufacturing. Pearson, 2013.

1	**Title of the course** (L-T-P-C)	**Engineering Mathematics for Advanced Studies** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	1. Module-1: Linear Algebra: Vector Spaces, Matrices, Linear algebraic equations, Eigenvalues and Eigen- vectors of matrices, Singular-value decomposition 2. Module-2: Tensor Algebra: Index Notation and Summation Convection, Tensor Algebra 3. Module-3: Vector Calculus: Dot and Cross Product, Curves. Arc Length. Curvature. Torsion, Divergence mand Curl of a Vector Field, Line Integrals, Green's Theorem, Stokes's Theorem, use of Vector Calculus in various engineering streams 4. Module-4: Ordinary Differential Equations: Initial Value Problem, Method to solve first order ODE, Homogeneous, linear, 2nd order ODE, Non-homogeneous, linear, 2nd order ODE, System of 1^{st} order ODE 5. Module-5: Laplace and Fourier transformation: First and Second Shifting Theorems, Transforms of Derivatives and Integrals, Fourier Cosine and Sine Transforms, Discrete and Fast Fourier Transforms. 6. Module-6: Partial Differential Equations: Basic Concepts of PDEs, Modeling: Wave Equation, Heat Equation, Solution by Separating Variables, Solution by Fourier Series, Solution by Fourier Integrals and Transforms 7. Module-7: Numerical Methods: Methods for Linear Systems, Least Squares, Householder's Tridiagonalization and QR-Factorization, Methods for Elliptic, Parabolic, Hyperbolic PDEs 8. Module-8: Complex Analysis and Potential Theory: The Cauchy-Riemann Equations, Use of Conformal Mapping, Electrostatic Fields, Heat and Fluid Flow Problems, Poisson's Integral Formula for Potentials 9. Module-9: Optimization and Linear Programming: Method of Steepest Descent, Linear Programming, Fundamental theorem of linear inequalities, Cones, polyhedra. and polytopes, Farkas' lemma, LP- duality, max-flow min-cut, Simplex Method, primal- dual, Fourier-Motzkin elimination, relaxation methods 10. Module-10: Probability Theory and Statistics: Experiments, Outcomes, Events, Permutations and Combinations, Probability Distributions, Binomial, Poisson, and Normal Distributions, Distributions of Several Random Variables, Testing Hypotheses, Goodness of Fit, $\chi 2$-Test. 11. Module-11: Abstract Algebra: Groups, Sub-groups, Cosets and Lagrange's theorem, Group actions, direct and semi-direct products
4	**Texts/References**	1. E. Kreyszig. Advanced Engineering Mathematics, John Wiley & Sons, 2011. 2. P.V. O'Neil. Advanced Engineering Mathematics, CENGAGE Learning, 2011. 3. D.G. Zill. Advanced Engineering Mathematics, Jones & Bartlett Learning 2016. 4. B. Dasgupta. Applied Mathematical Methods, Personal Education, 2006. 5. A. Schrijver, Theory of Linear and Integer Programming, 1998. 6. D.S. Dummit, R.M. Foote, Abstract Algebra, 2004.

1	**Title of the course** (L-T-P-C)	**Introduction to Programming and Modeling Laboratory** **1-0-3-5**
2	**Pre-requisite courses(s)**	--
3	**Course content**	SESSION A – Programming in C and Python 1. Elements of programming 2. Compiling - Coding and Machine representation 3. Integrated Development Environments (IDEs) 4. Types of Variables and Arrays 5. Control Loops 6. Functions 7. Introduction to source code version control 8. Best Practices and Documentation SESSION B – Introduction to Mathematical Toolkits 1. Basic programming syntax 2. Working with Arrays - Initialization of arrays, extracting intrinsic matrix properties 3. Evaluation of commonly used statistical metrics 4. Plotting for research – data visualization, data conditioning, different types of plots 5. Primer to Data Science SESSION C – Exposure to 3D modelling and grid generation 1. Use of software to create basic geometrical shapes 2. Grid generation and mesh quality assessment SESSION D – Software project 1. Hands-on implementation to appreciate comprehensive project execution
4	**Texts/References**	1. R. Pratap, Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers, Oxford, (2010). 2. C Programming Language– Brian Kernighan and Dennis Ritchie, Second Edition, Pearson Education India. 3. Technical guides, user manuals, and tutorials for various software packages

1	**Title of the course** (L-T-P-C)	**Research Methodology** **1-0-0-2**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Scientific Literature:** Research articles, resources, types of publications, identifying authentic sources **Reading:** Reading research articles; experimental, numerical, analytical, and review publications. **Writing:** Communicating formally (letters, emails) Styling; Units; Writing research articles; Automations using LaTeX, MS Word, Mendeley, BibTex; Research ethics **Presentations:** Presenting research work, Content and time management. Presentation tools: MS PowerPoint, Beamer, Excel; Plotting tools: Grapher, Origin, Tecplot, Matlab; Figures: quality, scaling, vector vs raster formats; **Oral Communication:** Stage manners, voice modulation **Hybrid Mode Presentations:** Initial setup and the tools required
4	**Texts/References**	1. A Manual for Writers of Research Papers, Theses, and Dissertations, Kate 2. L Turabian, Ninth Edition, The University of Chicago Press, 2018. 3. Communication Skills for Engineers and Scientists, Sangeeta Sharma and Binod Mishra, Second Edition, PHI Learning, 2009. 4. The elements of style, William Strunk Jr and E White, Fourth Edition, Pearson Education, 1999. 5. A New Approach to Research Ethics Using Guided Dialogue to Strengthen 6. Research Communities, Henriika Mustajoki and Arto Mustajoki, First Edition, Routledge Publications, 2017. **References:** 1. Wren and Martin “High School English Grammar and Composition”, 2. Regular edition, January 2017.

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***Allocate MTech Technical Project Supervisor at the end of 1st semester**

2nd Semester : 33 Credits

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Experimental Theory & Laboratory (ME 611)	1-0-3-5	To introduce students with experimental analysis, data analysis, measurement tools and to introduce basic and advance level experiments in Manufacturing	PC
Modeling and Simulation in Materials and Manufacturing (New)	2-1-0-6	To introduce different materials modeling and simulation techniques used at different time and length scales.	PC
Mechanics of Machining and Forming (New)	3-0-0-6	To introduce and orient students to the concepts of tool design and mechanics of machining, forming, FLD design, advancement in machining and forming.	PC
Seminar (ME 910)	0-0-0-4	Presentation to a large audience as seminar on research topics in Mechanical Engineering	PC
Elective I	3-0-0-6	To give a choice to the student to choose postgraduate level course	PE
Elective II	3-0-0-6	To give a choice to the student to choose postgraduate level course	PE

1	**Title of the course** (L-T-P-C)	**Modeling and Simulation in Materials and Manufacturing** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Density Functional Theory (DFT):** Introduction to DFT: Principles and theoretical foundations, Electron density, exchange-correlation functionals Predicting and analyzing material properties (e.g., electronic, optical, and magnetic). **Molecular Dynamics (MD) Simulations:** Basics of MD Simulation: Principles and algorithms, force fields, Energy minimization, Ensembles, Applications in studying dynamic material behavior: Estimation of glass transition temperature, polymer-metal/polymer-polymer/metal- filler/polymer-filler interaction energy. Estimation of bond and non-bond interactions. **Coarse-Grained (CG) simulations**: Coarse-Grained Modeling: Principles and techniques, force field: MARTINI, Applications in polymers and complex systems, Hands-on with CG models (MARTINI model). **Discrete Dislocation Dynamics**: Classification of defects, Dislocation Characteristics and classification, Dislocation plasticity, Stress field of a dislocation, Volterra construction, Dislocation motion, Driving force on a dislocation, Evaluation of dislocation velocity, Discretization and adaptive remeshing of dislocation lines, Time integration of equations of motion, Dislocation reactions **Introduction to ParaDis**: A discrete dislocation dynamics code **Continuum Modeling of Metals**: Crystal structure, slip systems, elastic and plastic deformation, anisotropy, Stress and strain tensors, principle stresses, Yield criteria, Hardening laws, Small and Large deformation theory, Constitutive modeling, Crystal Plasticity Finite Element Modeling, Software tools for continuum mechanics (ABAQUS, DAMASK, COMSOL), Deep drawing simulation, Extrusion simulation.
4	**Texts/References**	1. Understanding Molecular Simulation, From Algorithms to Applications, by Daan Frenkel and Berend Smit 2. Molecular Dynamics Simulation, Fundamentals and Applications, by Kun Zhou and Bo Liu 3. Ryan B. Sills, William P. Kuykendall, Amin Aghaei, Wei Cai, Fundamentals of Dislocation Dynamics Simulations, Multiscale Materials Modeling for Nanomechanics. Vol. 245. Springer 4. Franz Roters, Philip Eisenlohr, Thomas R. Bieler, Dierk Raabe Crystal Plasticity Finite Element Methods: In Materials Science and Engineering, John Wiley & Sons, 2011 5. Ellad B. Tadmor, Ronald E. Miller, Modeling Materials - Continuum, Atomistic and Multiscale Techniques, Cambridge University Press, 2011.

1	**Title of the course** (L-T-P-C)	**Mechanics of Machining and Forming** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Principles of metal cutting; Mechanics of chip formation; Geometry of cutting tools and tool signatures; Orthogonal and oblique cutting; Metal cutting models: Merchant model, Lee- Shaffer model; Forces in metal cutting; Thermal aspects of machining; Tool wear, tool life, tool materials, Overview of tool coatings and coating techniques; Economics of machining; Machinability; Cutting fluids: properties, types, application techniques, emissions and its adverse effects; Recent advances in machining: hard turning, high speed machining, diamond turning, machining of difficult to cut materials, machining with minimum quantity cutting fluids and cryogenic fluids; Metal forming: Bulk and sheet metal forming processes, Fundamentals of plasticity, yield, and flow, anisotropy, instability, yield criterion for isotropic materials, plastic stress-strain relations for isotropic materials. Force equilibrium method and its application to metal forming processes. Introduction to incremental sheet and bulk metal forming.
4	**Texts/References**	1. M. C. Shaw, Metal Cutting, Tata McGraw Hill, New Delhi, 2004. 2. M. C. Shaw, Principles of Abrasive Processing, Oxford University Press, 1996. 3. G. K. Lal, Introduction to Machining Science, New Age International Publishers, 2007. 4. G. Boothroyd and W. A. Knight, Fundamentals of Machining and Machine Tools, CRC-Taylor and Francis, 2006. 5. A. Ghosh and A. K. Malik, Manufacturing Science, East West Press, 2010. 6. Theory of Plasticity by J. Chakrabarty, McGraw-Hill Book Co., International Edition, 19874

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Semester – III: 32 Credits			**Semester – IV: 32 Credits**		
Course Name	L-T-P-C	Course Category	Course Name	L-T-P-C	Course Category
M.Tech. Project - I	0-8-16-32	IC	M.Tech. Project - II	0-8-16-32	IC