ANNEXURE 3

Master of Technology in Material Science and Technology (MST)

Course Structure and Syllabus

Semester I

S.No.	Course Name		Credits
1	Mathematical Foundations for Material Science and Technology	Core	4
2	Structure and Characterization of Materials	Core	4
3	Thermodynamics and Kinetics	Core	4
4	Elective I	Elective	4
5	Elective II	Elective	4

Semester II

S.No.	Course Name		Credits
1	Heat Treatment of Metals and Alloys	Core	4
2	Mechanical Behavior of Materials	Core	4
3	Processing of Engineering Materials	Core	4
4	Elective III	Elective	4
5	Elective IV	Elective	4

Semester III

S.No.	Course Name		Credits
1	Academic Ethics and Technical Writing	Core	4
2	Research Methodology	Core	4
3	Research Reading and Laboratory	Core	4
4	Seminar	Core	4
5	Minor Dissertation	Core	8

Semester IV

S.No.	Course Name		Credits
1	Major Dissertation	Core	16

Elective I and Elective II will be offered from the list of courses mentioned below

S.No.	Course Name	Credits
1	Advanced Operation Research	4
2	Defects in Materials	4
3	Fracture Mechanics and Fatigue	4
4	Selection and Manufacturing of Engineering Materials	4
5	Surface Engineering	4
6	Advanced Engineering Materials	4

Elective III and Elective IV will be offered from the list of courses mentioned below

S.No.	Course Name	Credits
1	Additive Manufacturing	4
2	Advanced Joining Processes	4
3	Modelling and Simulation in Materials Engineering	4
4	Mechanics of Composite Materials	4
5	Alternative Materials	4
6	Cryogenics	4

Syllabus

Core Courses

1. Mathematical Foundations for Materials Engineering

Introduction to Probability, Random variables; Expectation, Variance, Moment generating function, Characteristic function; Bivariate and multivariate distributions - Joint, marginal and conditional distributions, Covariance, correlation, order statistics; Central limit theorem, Sampling distributions, Theory of Estimation, Maximum likelihood estimation, Testing of Hypotheses.

Basic concepts of Partial Differential Equations, Modelling, Separation of variables, Fourier series solutions, Wave equation, method of characteristics, Heat equation, solution by Fourier series and Forurier integrals, Rectangular membrane, Laplace equation, solution by Laplace transforms.

Matrices and their properties (determinants, traces, rank, nullity) Subspaces, hyperplanes, Linear Dependence and Span, Basis, Eigenvalues and eigenvectors; Matrix factorizations; Inner products; Distance measures; Projections.

Linear programming, Simplex method, Duality in linear programming, Convex optimization and Quadratic programming; Least squares optimization, Unconstrained optimization; Newton method, Gradient descent, Stochastic gradient descent and Conjugate gradient descent methods; Constrained optimization, KKT conditions.

Suggested Reading:

- S. M. Ross, Probability Models, 11th Edition, Academic Press, 2014
- K. S. Trivedi, Probability and Statistics with Reliability, Queuing and Computer Science Applications, 2nd Edition, Wiley, 2004
- E. Kreyszig (with H. Kreyszig and E. Normington), Advanced Engineering mathematics, 10th Edition, Wiley, 2011.
- G. Strang, Linear Algebra and its Applications, 4th Edition, Cengage Learning, 2005
- W Forst, D Hoffmann, Optimization—Theory and Practice, Springer-Verlag New York, 2010

2. Structure and Characterization of Materials

Fundamentals of crystal structure, Bragg's condition, Laue treatment, reciprocal lattice, Determining Crystal structure, Concept of ASF and GSF, Experimental methods and estimation of stress and Scherrer Equation. Optical image formation, Resolution, Depth of Field and Depth of Focus, Light sources and condenser systems, Selection of objective lenses, Sampling and sectioning, Mounting and grinding, Polishing and Etching methods, Reflection and absorption of light, Bright field and dark field image contrast, Phase contrast microscopy, Working with digital images and Image interpretation. Components of SEM, Beam focusing conditions, Inelastic scattering and Energy losses, Characteristics of X-ray images and Image contrast in backscattered

electron images, Factors affecting secondary electron emission, Secondary electron image contrast, Sputter coating and contrast enhancement and Fractography, Principles of operation and construction and Ion beam-specimen interactions**.** Wave properties of electrons, Resolution limitations, Lens aberrations, Comparative performance of SEM and TEM, Specimen preparation: Mechanical thinning, Electrochemical thinning, Ion milling, Sputter coating, Carbon coating and Replica methods, Working principle and the origin of contrast in TEM, Principle of reciprocity in electron optics and Scanning TEM. Thermo-gravimetric analysis (TGA): Introduction, Instrumentation and Working principle; Differential Scanning Calorimetry (DSC): Introduction, Instrumentation and Working principle; and Raman Spectroscopy: Introduction, Instrumentation and Working principle

Suggested Reading

- Microstructural Characterization of Materials by David Brandon and Wayne Kaplan, 2nd Edition, 2008.
- Elements of X-ray Diffraction by B. D. Cullity, 3rd Edition, 2013.
- Materials Characterization Techniques by Sam Zhang, Lin Li, Ashok Kumar, 1st Edition, 2008.

3. Thermodynamics and Kinetics

Energy, Entropy, Irreversible and reversible processes, First and second laws of thermodynamics, Conditions for thermodynamic equilibrium, Helmholtz free energy and Gibbs free energy, Equilibrium in single component systems; Phase transformations. Solution thermodynamics, Equilibrium in multi-component systems, Phase rule, Phase diagrams, Reaction Equilibria, Thermodynamics of Point defects, Surfaces and Interfaces, Curvature Effects. Derivation of diffusion equations, description of diffusion sources, boundary conditions, temperature dependence, mechanisms of diffusion

Suggested Reading

- C.H.P. Lupis: Chemical Thermodynamics of Materials, Elsevier Science, 1982.
- Robert DeHoff: Thermodynamics in Materials Science (Second Edition), Taylor & Francis, 2006. P. Shewmon: Diffusion in Solids (Second Edition), TMS, 1998.

4. Heat Treatment of Metals and Alloys

Stress relieving, Annealing and its types, Spheroidizing, Normalizing, Hardening methods and Factors affecting hardening process, Tempering: Structural changes, Effect of alloying elements, Temper brittleness, Austempering, Martempering, Sub-zero treatment and Patenting, Heat treatable and non-heat treatable aluminium alloys, Classification, Heat treatment of cast and wrought aluminium alloys. Significance of hardenability, relationship of hardenability with transformation rates and Determination of hardenability, Factors affecting hardenability: Austenitic grain size, Carbon content and Alloying elements, Removal of heat during quenching, Quenching media and Characteristics of quenchants, Thermocouples: Thermocouple material and

its selection criteria, Temperature measurement and calibration, Indirect methods of temperature measurement and Temperature control. Carburizing types: Pack, Liquid, Gas and Vacuum; Post carburizing heat treatments, Cyaniding and Carbonitriding, Nitriding, Plasma nitriding, Salt bath nitrocarburizing, Boronizing, Chromizing and Toyota Diffusion (TD) process, Surface hardening types: Flame, Induction, Electron beam and Laser and Case depth measurement in steels. Classification, Controlled rolling, Hot-cold working, Ausforming, and Isoforming, Marstraining, Cryoforming, Preliminary TMT, Thermomechanical annealing and TMT of non-ferrous alloys, Low hardness and strength after hardening, Soft spots, Oxidation, Decarburizing, Overheating and Burning of steels; Distortion and Wrapping; Methods to reduce distortion and Treatment for stabilizing dimension. Inspection: Steps, Objectives, Manner, Process, Types and Stages; Factors controlling quality, Quality control, Quality control in heat treatment: Product design, Heat treatment specifications, Material selection, Dimensional considerations, Selection and working of equipment and accessories; Inspection in heat treatment, Energy economy through: Material change, Heat treatment practice and Processing; Air pollution in heat treatment

Suggested Reading

- Heat Treatment Principles and Techniques by T.V. Rajan, C.P. Sharma and Ashok Sharma, 2nd Edition, 2011.
- Heat Treatment of Metals by B. Zakharov, 1st Edition, 2002.
- Steel and Its Heat Treatment by Karl-Erik Thelning, Bofors Handbook, 1967.

5. Mechanical Behaviour of Materials

Linear: continuum; isotropic; anisotropic; multiaxial; atomistic basis, Nonlinear in crystalline materials: pseudoelasticity, Viscoelasticity: elasticity and fluidity. Limit of elastic response: uniaxial and multiaxial, Mechanisms in crystalline materials: dislocations, twins, and APBs, Mechanisms in noncrystalline materials, Strengthening via microstructure, environment, and physical size. Evolution of fracture models: ultimate failure, Microstructural mechanisms of fracture strengthening. Failure below fracture stress: insidious failure, Empirical fatigue models, Microstructural mechanisms of prolonged fatigue lifetime. Time-dependent plasticity, Deformation mechanism maps of elastoplasticity

Suggested Reading

- Courtney. Mechanical Behavior of Materials. 2nd ed. Long Grove, IL: Waveland Press Inc., 2005. ISBN: 9781577664253.
- Mechanical Metallurgy | 3rd Edition by George E. Dieter | 1 July 2017

6. Processing of Engineering Materials

Fundamentals of metal casting; metal casting processes; Particulate processing of metals Characterization of engineering powders; production of metallic powders; conventional pressing and sintering; alternative pressing and sintering techniques, materials and products, design considerations. Processing of traditional and new ceramics, processing of cermets, product design

considerations. Fundamentals in metal forming, bulk deformation processes- rolling, forging, extrusion, drawing. Fundamentals of welding, gas flame and arc processes, resistance and solid-state welding processes, other welding processes- brazing and soldering, adhesive bonding, mechanical fastening and joining of non-metals. Extrusion, plastic moulding, different types of plastic moulding, processing of elastomers. Composite materials: processing of polymers–matrix composites, metal-matrix and ceramic-matrix composites, design considerations.

Suggested Reading

- Fundamentals of Modern Manufacturing, M.P. Groover.
- DeGramo's Materials and Processing in Manufacturing, J.T. Black and R. A. Kohser.
- Manufacturing Engineering and Technology, S. Kalpakjian, S.R. Schmid.

7. Academic Ethics and Technical Writing

Significance and ways to carry out literature review; Structure and components of a research report, project proposal and research paper; Ethics: definition, moral philosophy, nature of moral judgements and reactions; Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP); Redundant publications: duplicate and overlapping publications, salami slicing; Selective reporting and misrepresentations of data; Publication ethics; Conflicts of interest; Publication misconduct and its identification; Violation of publication ethics, authorship and contributorship; Predatory publishers and journals; Open access and subscription based publications; Online resource to check publisher copyright and self-archiving policies; Journal finder tools; Conflict of interest; Plagiarism and its detection tools; Indexing and citation databases; Impact factor; h-index; g-index; i10 index etc.

Suggested Reading

- Ethics in Science Education, Research and Governance, Edited by K. Muralidhar, A. Ghosh, & A.K. Singhvi. New Delhi: Indian National Science Academy. ISBN: 9788193948217, 2019.
- Research Evaluation Metrics. UNESCO Curriculum for Researchers by U. Kanjilal and A.K. Das, ISBN: 978-92-3-100082-9, 2015.
- Concepts of openness and open access by D.P. Madalli, ISBN: 978-92-3-100079-9, 2015.

8. Research Methodology

Research: meaning, objective and types; Research process; Criteria of good research; Research problem: meaning, necessity to define and techniques involved in defining a research problem; Research design: meaning, need, characteristics and types; Sampling design: implications, steps,

selection criteria, characteristics, types and concept of random sample; Measurement techniques: scales, source of errors, sound measurement and techniques of developing measuring tools; Scaling techniques: meaning, classification, various scaling and scale construction techniques; Data collection techniques; Processing and analysis of data: processing operations, elements of analysis, statistics in research and regression analysis; Sampling: need, fundamental terminologies, sampling distributions sampling theories, estimation and sample size; Hypotheses testing: significance, procedure, various parametric tests; Chi-square test, ANOVA and Multivariate analysis techniques.

Suggested Reading

- Research Methodology: Methods and Techniques by C.R. Kothari, ISBN (13): 978-81-224-2488-1, 2nd Edition, 2004.
- Research design: Qualitative, Quantitative, and Mixed Methods Approaches by J.W. Creswell and J.D. Creswell, 5th Edition, 2019.
- Management Research Methodology: Integration of Principles, Methods and Techniques by K. N. Krishnaswamy, M. Mathirajan and Appa Iyer Sivakumar, 1st Edition, 2006.

9. Research Reading and Laboratory

The student will read research papers, and related thesis reports which are relevant to his/her area of work and any other technical or scientific literature, which the supervisor may assign for a better understanding of the domain in which the student is pursuing his/her doctoral research work. This course would be evaluated by the concerned supervisor.

10. Seminar

The Seminar course would include seminars related to the dissertation work. This course would be evaluated by a seminar evaluation committee comprising atleast three faculty members.

11. Minor Dissertation

Student would pursue the minor dissertation in the school and submit it to the school for evaluation. The dissertation of each student is to be evaluated, through viva-voce/ presentation, by the minor dissertation evaluation committee of the School.

12. Major Dissertation

Student would pursue the major dissertation in the school and submit it to the school for evaluation. The dissertation of each student is to be evaluated through viva-voce/ presentation in the school conducted by the committee comprising the supervisor and one external expert, from outside the

university, in the related area, as recommended by the special committee of the School and approved by the Competent Authority of the University.

Elective Courses

1. Advanced Operations Research

Convex sets, graphical and simplex method, artificial variable techniques, revised simplex method, duality theory, dual simplex method, revised dual simplex method. Introduction, inventory models, economic order quantity (EOQ), deterministic and probabilistic inventory models, inventory control. Network diagram, project planning using critical path method (CPM) and program evaluation review technique (PERT), crashing of network, simulation techniques. Pure and mixed strategies, minimax (maximin) criterion of optimality, solution of various models in game theory by graphical and linear programming technique, rules of dominance. Solution of multi-objective programming problems by graphical and simplex method. Convex functions and their properties, Kuhn Tucker theory, convex quadratic programming, Wolfe's and Beale's algorithm, Separable convex programming

Suggested Reading

- Taha,H. A., Operations Research - An Introduction, Tenth Edition, Pearson Education, 2017.
- Rao,S. S., Engineering Optimization, Theory and Practice, Fourth Edition, John Wiley, 2009.
- Deb, K., Optimization for Engineering Design, Algorithms and Principles, PHI, 2010.
- S.D. Sharma, Operations Research, S. Chand company.
- Kanti Swarup, P. K. Gupta and Manmohan, Operations Research.
- O.L. Mangasarian, Non-Linear Programming, McGraw Hill, New Delhi.

2. Cryogenic Engineering

Historical development, Applications of Cryogenics (Space, Food Processing, Super conductivity, Electrical Power, Biology, Medicine, Electronics and Cutting Tool Industry). Low Temperature Properties: Properties of Engineering Materials (Mechanical properties, Thermal properties, Electric and Magnetic properties), Properties of Cryogenic fluids. Ideal system, Joule Thomson expansion, Adiabatic expansion, Linde Hampson Cycle, Claude & Cascaded System. Introduction to Cryogenic Refrigeration Systems: Magnetic Cooling, Stirling Cycle Cryo Coolers. Ideal refrigeration systems, Refrigeration using liquids and gases as refrigerant, Refrigerators using solids as working media. General liquefaction systems. Liquefaction systems for Neon, Hydrogen and Helium. Critical components of liquefaction systems. Cryogenic storage vessels and transportation. Thermal insulation and their performance at cryogenic temperatures, Super insulations, Vacuum insulation, Powder insulation. Cryogenic fluid transfer systems. Pressure, flow-rate, liquid-level and temperature measurements. Types of Heat Exchangers used in cryogenic systems (only description with figure). Cryo Pumping Applications

Suggested Reading

- J. H. Boll Jr, Cryogenic Engineering
- R. B. Scott, Cryogenic Engineering, Van Nostrand Co.,1959
- Randal F.Barron, Cryogenic systems, McGraw Hill, 1986
- Klaus D.Timmerhaus and Thomas M.Flynn, Cryogenic Process Engineering, Plenum Press, New York, 1989.

3. Fracture Mechanics and Fatigue

Fracture mechanics approach to design, historical perspective, Effect of material properties on fracture. Introduction- Fracture mechanics approach to design, Effect of material properties on fracture, Linear Elastic Fracture Mechanics (LEFM) approach: Energy based approach, stress based approach; fracture mechanics based on plane stress and plane strain conditions. Crack tip plasticity, Crack tip opening displacement, J- contour integral, fracture toughness crack-growth resistance curves, J- controlled fracture. Fatigue phenomenon; loading patterns and characteristics; Fatigue design criteria; Fatigue testing methodology and life prediction. Stress based approach to life estimation: Wöhler-diagrams/S-N curves, Mean-stress effects on S-N behaviour, Factors influencing S-N behaviour, S-N representation and approximation, Cyclic stress-strain behaviour, Strain based approach to life estimation, Variable amplitude loading and cumulative damage theories, Paris law - Fatigue life and crack growth estimation.

Suggested Readings:

1. Anderson T L, Fracture Mechanics – Fundamentals and Application, 3rd Edition, Taylor and Francis, 2005.
2. Ralph I. Stephens, Ali Fatemi, Robert R. Stevens, Henry O. Fuchs, Metal Fatigue in Engineering, 2nd Edition, John Wiley & Sons, 2001.

4. Alternative Materials

Historical developments in polymeric materials, Basic concepts & definitions: monomer & functionality, oligomer, polymer, repeating unites, degree of polymerization, molecular weight & molecular weight distribution, Chemical & Physical structure, properties, source, important chemical modifications, applications of polymers such as cellulose, lignin, starch, rosin, shellac, latexes, vegetable oils and gums, proteins etc. Biopolymers (and polymers in general) Structure Mechanical properties Hygroscopic effects (swelling, moisture-softening, the dependence of creep rate on moisture content etc.) Manufacturing processes Theory of elasticity and viscoelasticity Mechanical models for linear viscoelastic response Creep, stress relaxation and dynamic mechanical testing, Fracture and fatigue. Bio composite materials Introduction Mechanical properties and applications Manufacturing and testing Biodegradation and recycling. Introduction of biomaterials, requirements & classification of biomaterials, Types of Biomaterials- Degradable and resorbable biomaterials- engineered natural materials- Biocompatibility-Hydrogels-pyrolitic carbon for long term medical implants-textured and porous materials-Bonding types- crystal

structure-imperfection in crystalline structure-surface properties and adhesion of materials – strength of biological tissues-performance of implants-tissue response to implants- Impact and Future of Biomaterials. Introduction to ceramics, Comparison of properties with metals and polymers, bonding-covalent and ionic, important ceramics structures, coordination, ionic radii, Ambipolar Diffusion, Kroger Vink notation of point defects, defect reactions. Effect of Chemical Forces on Physical Properties: Melting Points, Thermal Expansion & Surface Energy. Thermodynamic and Kinetic Considerations: Free Energy, Chemical Equilibrium, Chemical Stability Domains, Gibbs-Duhem Relation for Binary Oxides, Kinetic Considerations, Phase diagrams and their importance.

Suggested Reading

- C. Barry Carter, M. Grant Norton, Ceramic Materials- Science and Engineering, Second Edition, Springer New York, 2013
- Billmeyer F, 'Textbook of Polymer Science', Wiley Interscience, 1994 2.
- Principles of Polymer Science, Bahadur and Sastry, Narosa Publishing House 2002.

5. Advanced Engineering Materials

Crystal structure, Silicate ceramics, Imperfections in ceramics, Types of ceramic materials, Fracture behaviour, Stress-strain curve, applications of ceramics: Refractories, Abrasives, cements etc., Fabrication and processing of glasses, glass-ceramics and clay product; Powder pressing and Tape casting. Polymer molecule chemistry, Molecular configuration, Polymer types, Defects and diffusion in polymeric materials, Stress-strain behaviour, Mechanical properties and Factors affecting mechanical properties of polymers, Crystallization, Melting, Glass-transition, Polymerization, Additives and Forming techniques. Principle of combined action, Matrix phase, Reinforcement, Rule of mixture, Classification and tensile stress-strain behavior of different types of composites, Fabrication/processing, properties and applications of different types of composites. History and scope, Classification, and Effect of Nano-dimensions on Materials Behaviour, Synthesis Routes: Bottom-Up Approaches, Top-Down Approaches and Consolidation of Nanopowders, Applications of nanomaterials, Concerns and Challenges of Nanotechnology. Functionally Graded Materials: Introduction, Composition, Fabrication, Properties and Applications; Smart Materials: Introduction, Composition, Fabrication, Properties and Applications; and Super alloys: Introduction, Composition, Fabrication, Properties and Applications

Suggested Reading

- Materials Science and Engineering an Introduction by William D. Callister and David G. Rethwisch, 10th Edition, 2018
- Textbook of Nanoscience and Nanotechnology by B.S. Murthy, P. Shankar, Baldev Raj, B.B. Rath and James Murday, 1st Edition, 2016.

- Advanced Engineering Materials and Modeling by Ashutosh Tiwari, N. Arul Murugan and Rajeev Ahuja, 2016.

6. Additive Manufacturing

Introduction to AM, AM evolution, Distinction between AM & CNC machining, Steps in AM, Classification of AM processes, Advantages of AM and Types of materials for AM. Stereolithography (SL), Materials, Process Modeling, SL resin curing process, SL scan patterns, Micro-stereolithography, Mask Projection Processes, Two-Photon vat photopolymerization, Process Benefits and Drawbacks. Material Jetting AM Processes, Binder Jetting AM Processes, Research achievements in printing deposition, Technical challenges in printing. Fused Deposition Modelling (FDM), Principles, Materials, Process Modelling, Plotting and path control, Bio-Extrusion, Contour Crafting, Applications of Extrusion-Based Processes, case studies. Sheet Lamination AM Processes: Bonding Mechanisms, Materials, Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC), Gluing, Thermal bonding, LOM and UC applications, case studies. Selective laser Sintering (SLS), Electron Beam melting (EBM), Process Benefits and Drawbacks, Applications of Powder Bed Fusion Processes, case studies. Directed Energy Deposition AM Processes, Laser Engineered Net Shaping (LENS), Direct Metal Deposition (DMD), Electron Beam Based Metal Deposition, Friction stir additive manufacturing: Additive friction stir deposition process, functionally graded additive manufacturing components, Case studies. Wire Arc Additive Manufacturing: Process, parameters, applications, advantages and disadvantages, case studies. Multifunctional and graded materials in AM, Role of solidification rate, Evolution of non-equilibrium structure, microstructural studies, Structure property relationship, case studies. Post Processing of AM Parts: Support Material Removal, Surface Texture Improvement, Accuracy Improvement, Aesthetic Improvement, Preparation for use as a Pattern, Property Enhancements using Non-thermal and Thermal Techniques, case studies. Guidelines for Process Selection: Introduction, Selection Methods for a Part, Challenges of Selection, Example System for Preliminary Selection, Process Planning and Control.

Suggested Reading

- Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004.
- Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, D.T. Pham, S.S. Dimov, Springer 2001.
- Rapid Prototyping: Principles and Applications in Manufacturing, Rafiq Noorani, John Wiley & Sons, 2006.
- Additive Manufacturing, Second Edition, Amit Bandyopadhyay Susmita Bose, CRC Press Taylor & Francis Group, 2020.
- Additive Manufacturing: Principles, Technologies and Applications, C.P Paul, A.N Junoop, McGrawHill, 2021.

7. Advanced Materials Joining Processes

Introduction to advanced materials joining processes; microjoining and nanojoining, wire ball bonding; Advanced resistance welding, induction welding, Stud welding; Magnetically impelled arc welding; Fundamentals and types of laser welding including hybrid processes; Advanced GMAW and GTAW, activated GTAW; Plasma arc welding, electron beam welding; pressure welding; ultrasonic welding; explosive welding; diffusion bonding; Friction Welding, friction stir welding; electro-magnetic pulse welding; welding of super alloys, additive manufacturing/ 3D printing, fundamentals of welding automation, welding sensors and data acquisition; Welding process modeling and optimization; principles of robotic welding; weld defects; nondestructive inspection and testing of weldments. Mechanical and Microstructural characterization of welds.

Suggested Reading

- Welding Fundamentals and Processes, ASM Handbook, Vol 6 A, November 2011, AM International
- Welding Handbook, Welding Processes Part 2, Vol. 3, AWS, 2004.
- Y N Zhou, Microjoining and Nanojoining , Woodhead publishing, 2008.
- W Steen, Laser Material Processing, Springer-Verlag, 1991.
- Liming Liu, Welding and Joining of Magnesium Alloys, Woodhead Publishing, 2010. 6. L-E Lindgren, Computational welding mechanics, Woodhead Publishing Limited 2007.

8. Selection and Manufacturing of Engineering Materials

Basics of metals, ceramics, polymers, glasses, quasicrystals, amorphous solids, composites, hybrid materials, graphite, diamond, graphene, nanotubes. The evolution of engineering materials, design limiting properties such as density, cost, mechanical, thermal, wear, corrosion/oxidation etc.

Selection criteria for different engineering applications: automotive, aerospace, marine etc. Data driven selection approach using the Ashby charts for various engineering applications. Casting processes, forming processes such as rolling, extrusion, forging, sheet metal forming, formability, powder based manufacturing processes, single crystal development etc.

Various joining processes (fusion as well as solid state methods), advanced machining processes, fabrication of micro and nano scale systems. Principles of subtractive manufacturing and additive manufacturing, opportunities, limitations.

Considerations w.r.t technology development based on application, economics and deployment. Selective case studies

Suggested Reading:

- Materials selection in mechanical design, M. F. Ashby, fourth edition, Elsevier, 2011.
- Manufacturing Engineering and Technology, S. Kalpakjian, S. R. Schmid, Pearson, 2002

9. Surface Engineering

Thermodynamics of surface, surface dependent engineering properties, surface initiated engineering failure; mechanisms of surface degradation via wear, corrosion and high temperature oxidation; and importance, scope and classifications of surface engineering methodologies. Surface engineering practices: cleaning, pickling, etching, grinding, buffing etc., Conventional surface modification methods: flame hardening, induction hardening, carburizing, nitriding, diffusion assisted surface alloying, and advanced surface modification methods: laser, plasma and electron beam assisted surface modification. Surface coating via physical route: thermal evaporation, sputtering and pulsed laser deposition; and Surface coating via chemical route: chemical vapor deposition, laser assisted chemical vapor deposition. Surface engineering by material addition like weld overlay, surface cladding, hot dipping, solid state surface engineering: friction surfacing and stir processing, surface composites and thermal spraying techniques like flame spraying and HVOF spraying. Microstructural and compositional characterization of coatings and evaluation of surface-properties, economics and energy considerations, designing of surface engineering processes

Suggested Reading

- Surface Engineering for Corrosion and Wear Resistance, ASM International, Materials Park, Ohio, 2001.
- Materials and Surface Engineering by J.P. Davim, Woodhead Publishing, USA, 2012.
- Surface Engineering of Metals Principles, Equipment, Technologies by Tadeusz Burakowski and Tadeusz Wierzchoń, 1998.
- Surface Engineering for Wear Resistances by K.G. Budinski Prentice Hall, Englewood Cliffs, 1988.

10. Modelling and Simulation in Materials Engineering

Introduction, Lagrange and Newton interpolations, Gregory-Newton interpolation, Hermite interpolation, Piecewise and spline interpolation, Bivariant interpolation, least squares approximation. Convergence theory, Jacobi, gauss-Seidel, SOR, Global Iterative methods-CG type methods & steepest descent. Bisection method, Secant, Newton Raphson method, Predictor and corrector method, Runge-Kutta method. explicit and implicit method, mid-point rule, Trapezoidal rule, Simpson's rule, quadrature formula. direct method, variational method, weighted residual method, point and subdomain collocation method, Galerkin method, least squares method, application of FEM to material engineering problems in one and two dimensions.

Suggested Reading

- Saad, Y. “Iterative methods for linear spare system”, 2nd edition.
- Kreyszig E. “Advanced Engineering Mathematics”, 10th edition.
- Ferziger, J. H. and Peric, M., “Computational Methods for Fluid Dynamics”, 3rd Edition.
- Jain, M. K., Iyenger S. R. K. and Jain, R. K., “Numerical Methods” 2nd Edition.
- Zeinkeiwicz, O. C. and taylor R.C. “The Finite Element Method”, 5th Edition.
- Reddy, J. “An Introduction to Finite Element Method”, 3rd edition.

11. Defects in Materials

Equilibrium Point Defect Concentrations Intrinsic Point Defects Extrinsic Point Defects Diffusion Impurity diffusion, Description of dislocations Elements of Elastic Theory Stress Field of a Dislocation Strain Energy of a Dislocation Line Tension Forces on Dislocations Forces Between Dislocations Dislocation Reactions Dislocations in FCC Crystals Dislocations in Other Crystal Systems Dislocation Multiplication Strength of Crystalline Solids, Interface Defects: Twin Boundaries Stacking Faults Grain Boundaries Interface Boundaries Surface Defects: Description of Surface Structure Surface Crystallography Surface Relaxation and Reconstruction Crystal Growth

Suggested Reading

- D. Hull and D. J. Bacon, Introduction to Dislocations, 3rd Edition, Pergamon Press,
- J. Weertman and J. R Weertman, Elementary Dislocation Theory, Oxford, 1992. P. Shewmon, Diffusion in Solids,
- J. P. Hirth, Theory of Dislocations, 2nd edition, A Wiley-Interscience Publication, 1982.

12. Mechanics of composite materials

Classification and characteristics of composite materials, mechanical behaviour of composite materials, advantages of composites, applications and examples, stress-strain relation for anisotropic materials, orthotropic materials and isotropic materials, role of fiber orientation on stress-strain relation, strength of orthotropic lamina, different failure criteria for lamina Volume and mass fractions, density and void content, Determination of material constants, mechanics of material approach to stiffness, elasticity approach to stiffness, comparison of tensile and compressive strengths in fiber directions, classical laminate theory, stress-strain variation in laminate, resultant laminate forces and moments, strength of laminate and interlaminate stresses, Failure criterion for laminate, special cases of laminates – symmetric, cross-ply, angle-ply, balanced, etc., and design issues related to Impact, fracture and fatigue resistance.

Suggested Readings:

- P. K. Mallick, Fiber reinforced composites – Materials, Manufacturing and Design, 3rd Edition, CRC Press, Taylor and Francis, 2008.
- R. M. Jones, Mechanics of Composite Materials, 2nd Edition, Taylor and Francis, 1999.
- Autar K Kaw, Mechanics of Composite Materials, 2nd Edition, CRC Press, Taylor and Francis, 2006.