Mechanical Engineering

M. Tech Mechanical Engineering						
Sr No	**Course Code**	**Course Name**	**L**	**T**	**P**	**C**
1	ME 607	**Advanced Solid Mechanics**	3	0	0	6
2	ME 608	**Advanced Mechanisms and Dynamics of Mechanical Systems**	3	0	0	6
3	ME 609	**Advanced Fluid Mechanics and Heat Transfer**	3	0	0	6
4	ME 605	**Additive and Forming Manufacturing Processes**	3	0	0	6
5	ME 651	**Engineering Mathematics for Advanced Studies**	4	0	0	8
6	ME 427	**Mathematics for Data Science**	3	0	0	6
7	MA 401	**Numerical Linear Algebra**	3	0	0	6
8	MA 406	**Introduction to Numerical Methods**	3	1	0	4
9	CS 626	**Topics in Data Structures and Algorithms**	2	0	2	6
10	CS 434	**Programming Parallel Machines**	3	0	0	6
11	CS 601	**Software Development for Scientific Computing**	3	0	0	6
12	ME 603	**Advanced Finite Element Methods**	3	0	0	6
13	ME 601	**Advanced Heat Transfer**	3	0	0	6
14	ME 653	**Combustion and Fire Dynamics**	3	0	0	6
15	ME 705	**Convective Heat Transfer**	3	0	0	6
16	ME 637	**Design of Mechatronic Systems**	3	0	0	6
17	ME 652	**Fatigue and Fracture Mechanics**	3	0	0	6
18	ME 427	**Fluid Flow and Heat Transfer in Porous Media**	3	0	0	6
19	ME 646	**Fracture Mechanics**	3	0	0	6
20	ME 629	**Fundamentals of Acoustics**	3	0	0	6
21	ME 502	**Fundamentals of Tribology**	3	0	0	6
22	ME 602	**Introduction to Turbulence and its Modelling**	3	0	0	6
23	ME 628	**Mechanical Vibrations**	3	0	0	6
24	ME 625	**Linear Viscoelasticity**	3	0	0	6
25	ME 627	**Mechanics of Composite Materials**	3	0	0	6
26	ME 631	**Metal Forming and Plasticity**	3	0	0	6

27	ME 606	**Nonlinear Solid Mechanics for Finite Element Method**	3	0	0	6
28	ME 630	**Turbomachinery Aerodynamics**	3	0	0	6
29	ME 802	**Applied Elasticity**	2	1	0	6
30	ME 303	**Kinematics and Dynamics of Machines**	3	1	0	8
		Total Credits				

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Advanced Solid Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Module 1: Analysis of Stress:** Concept of traction, Cauchy Stress formula: Traction on arbitrary planes, Equality of cross-shears, Principal stresses and Principal Planes, Stress invariants, State of Stress Referred to Principal Axes Octahedral stresses, Mohr's Circles for 3D State of Stress, Equations of equilibrium – Cartesian and Cylindrical coordinate systems. **Module 2: Analysis of Strain:** Displacement field, Deformation gradient, change in length of a linear element andits linearization and physical interpretation, State of Strain at a point, change in the direction of a linear element, cubical dilatation, change in the angle between two linear elements – shear strain, Principal axes of strain and Principal strains, Strains in cylindrical coordinate systems, compatibility of linear strains. **Module 3: Stress-strain Relations – Linear Elastic Solids:** Generalized Hooke's Law, Material Symmetry Planes Monoclinic, Orthotropic, and Isotropic, Lames's constants, Bounds on moduli. **Module 4: Formulations, General theorems, and Solution Strategies:** Stress formulation – Beltrami-Michell Compatibility relations, Navier-Lame Equations of equilibrium, Strain Energy Concept, Saint Venants principle, Principle of Superposition, Uniqueness theorem; General Solution strategies. **Module 5: Plane elasticity:** Plane stress, Pane strain, 2D stress formulation in Cartesian and Polar Coordinates: Airy stress function. **Module 6: 2D Problems:** Cartesian coordinate Problems: Using Polynomials and Fourier series, Polar coordinate Problems: Axisymmetric problems - Lame, Rotating Disk, curved beams under pure moments, Infinite/Semi-infinite body subjected to concentrated loads – Kelvin and Flamant problems, Stress concentration in an infinite plate with a small hole – Kirsch problem. **Module 7: Extension, Flexure and Torsion of Prismatic bars:** Extension formulation; Torsion formulation: SaintVenants semi-inverse approach, Prandtl's stress function approach, Membrane analogy, Solution using Fourier series, Torsion of thin-walled tubes – Bredt-Batho formula; Flexure formulation without twist.

4	**Texts/References**	**Textbooks:** **1.** M.H. Sadd,"Elasticity: Theory, Applications and Numeric”, Academic Press, 2013. **2.** J. R. Barber, Elasticty, Springer, 2010. **3.** L.S. Srinath, “Advanced Mechanics of Solids" Tata McGraw Hill, 2007. **References:** **1.** S.P. Timoshenko and J.N. Goodier, “Theory of Elasticity,” McGraw-Hill, Third Ed., New York,1970. **2.** Allan F. Bower, Applied mechanics of Solids. CRC press, 2009. **3.** Adel S. Saada, Elasticity: Theory and Applications, Second Edition, Revised & Updated. J. Ross Publishing, ,2009. **4.** Robert William Soutas-Little,Elasticity, Courier Corporation, 2012.

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1	**Title of the course** (L-T-P-C)	**Advanced Mechanisms and Dynamics ofMechanical Systems (3-0-0-6)**
2	**Pre-requisite courses(s)**	

3	**Course content**	• Review of Grash of criterion and its derivation
		• Synthesis of Mechanisms - Four bar linkage and Slider crank mechanisms.
		  ○ Two position Double rocker design
		  ○ Two position motion generation
		  ○ Three position motion generation
		  ○ Function Generation
		  ○ Synthesis of crank-rocker for a specified rocker amplitude
		• Path synthesis -- practical Approaches
		  ○ Roberts Cognate Theorem
		• Review of Special Mechanisms
		  ○ Straight Line generating mechanisms.
		  ○ Ackermann Steering Mechanism
		  ○ Pantograph Mechanism and its derivation
		• Brief introduction to spatial linkages
		  ○ Serial Chain
		  ○ Closed loop linkages
		• Review of Dynamics of particles
		  ○ Newton's laws, Impulse Momentum
		  ○ Moment of a force and Angular Momentum, Work and Energy
		  ○ System of particles
		• Fundamentals of Analytical Mechanics
		  ○ Degrees of freedom and generalized coordinates
		  ○ Systems with constraints
		  ○ The stationary value of a function and a definite integral
		  ○ The principle of virtual work
		  ○ D' Alembert's principle
		  ○ Hamilton's principle
		  ○ Lagrange's equation of motion
		  ○ Lagrange's equations for impulsive forces
		  ○ Conservation laws
		  ○ Routh's method for ignoration of coordinates
		  ○ Rayleigh's dissipation Function
		  ○ Hamilton's equations

4	**Texts/References**	**TEXTBOOKS** **1.** "Kinematics Dynamics and Design of Machinery", Kenneth Waldron and Gary L. KInzel, Second Edition, John Wiley, and Sons. **2.** "Analytical Dynamics", Leonard Meirovitch, First Edition, McGraw Hill

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1	**Title of the course** (L-T-P-C)	**Advanced Fluid Mechanics and Heat Transfer (3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	Boundary layer theory: fundamentals, derivation of N-S equations, exact solutions of N-S equations, Boundary-layer equations in plane flow, coupling of thermal boundary layers and velocity field of the temperature field, internal flows Potential flow and flow past immersed bodies. Turbulence: high Re flows, energy-transfer concepts, turbulent boundary layers, free-shear flows like jets, wakes, andmixing layers, turbulence modelling Compressible flows: energy equation, assumptions, compressible flows, stagnation properties, speed of sound, isentropic and non-isentropic flows, potential and rotational flows, effect of area change, shaft work, heat addition, mass addition and friction on flow states in a compressible (channel) flow. Pool Boiling: Nukiyama curve, boiling regimes, correlations, enhancement of boiling heat transfer Two phase flow and heat transfer: liquid-vapor interface, contact angle hysteresis, bubble formation, flow regimes,flow models, condensation. Radiation: Intensity, radiosity, irradiance, view factor geometry and algebra, radiative heat transfer equation, extinctionand scattering properties of gases and aerosols, overview of solution methods and applications. Radiation in Enclosures – Gas Radiation – Diffusion and Convective Mass Transfer – Combined Heat and Mass Transfer
4	**Texts/References**	**Texts:** **1.** Hermann Schlichting, and Klaus Gersten. Boundary layer theory. 9th edition. Springer, 2017. **2.** Tennekes, Hendrik, and John L. Lumley. A first course in turbulence. MIT press, 2018. **3.** Anderson, John D. Modern compressible flow. Tata McGraw-Hill Education, 2003. **4.** Carey, Van P. Liquid-vapor phase-change phenomena: an introduction to the thermophysics of vaporizationand condensation processes in heat transfer equipment. CRC Press, 2018. **5.** Incropera, Frank P., et al. Fundamentals of heat and mass transfer. Wiley, 2007. **6.** Modest, Michael F. Radiative heat transfer. Academic press, 2013. **References:** **1.** Davidson, Peter Alan. Turbulence: an introduction for scientists and engineers. Oxford University press, 2015. **2.** Pope, Stephen B. "Turbulent flows." (2001): 2020. **3.** Bejan, Adrian. Convection heat transfer. John Wiley & Sons, 2013. **4.** Kays, William Morrow. Convective heat and mass transfer. Tata McGraw-Hill Education,2011.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Additive and Forming Manufacturing Processes (3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Module 1:** Introduction to Smart manufacturing, various Smart Manufacturing Technologies, Smart foundry, Reverse engineering, Traditional manufacturing, Rapid Tooling, Rapid Manufacturing; Indirect Processes - Indirect Prototyping, Indirect Tooling, Indirect Manufacturing. Introduction to Additive Manufacturing (AM): Overview of Additive Manufacturing (AM), Introduction to flexible manufacturing processes **Module 2:** AM technologies, classification of AM processes: Sheet Lamination, Material Extrusion, Photo- polymerization, Powder Bed Fusion, Binder Jetting, and Direct Energy Deposition, Popular AM processes. Additivemanufacturing of different materials **Module 3:** Advance in welding techniques, Robotic welding, characterization, Non-traditional Manufacturing processes, **Module 4:** Introduction: CAD/CAM, NC/CNC, CNC machines, Industrial applications of CNC, economic benefits of CNC. CNC Machine Tools, CNC tooling: Qualified and pre-set tooling, tooling systems, tool setting, automatic tool changers, work holding and setting. Programming: Part programming language, programming procedures, proving part programmes, computer aided part programming **Module 5:** 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 bulkmetal forming. **Module 6:** Industry 4.0 cases studies of manufacturing
4	**Texts/References**	**1.** Gibson, D. W. Rosen, and B. Stucker, Additive Manufacturing Technologies: Rapid Prototyping DirectDigital Manufacturing. Springer, 2014. **2.** C. K. Chua and K. F. Leong, Rapid Prototyping: Principles and Applications in Manufacturing.WorldScientific, 2003. **3.** Theory of Plasticity by J. Chakrabarty, McGraw Hill Book Co., International Edition, 19874. **4.** Messler, R. W. (2008). Principles of Welding: Processes, Physics, Chemistry, and Metallurgy. Germany:Wiley. **5.** Ibrahim Zaid, R. Sivasubramanian, CAD/CAM: Theory and Practice. McGraw Hill Education,2nd edition,2009. **6.** M. P. Groover, E. W. Zimmers, CAD/CAM: Computer-aided design and manufacturing. Pearson, 2013.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Engineering Mathematics for Advanced Studies (4-0-0-8)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Module-1:** Linear Algebra: Vector Spaces, Matrices, Linear algebraic equations, Eigenvalues and Eigenvectors of matrices, Singular-value decomposition **Module-2:** Tensor Algebra: Index Notation and Summation Convection, Tensor Algebra **Module-3:** Vector Calculus: Dot and Cross Product, Curves. Arc Length. Curvature. Torsion, Divergence and Curl of a Vector Field, Line Integrals, Green's Theorem, Stokes's Theorem, use of Vector Calculus in various engineering streams **Module-4:** Ordinary Differential Equations: Initial Value Problem, Method to solve first order ODE, Homogeneous, linear, 2nd order ODE, Nonhomogeneous, linear, 2nd order ODE, System of 1st order ODE. **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 **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 **Module-7:** Numerical Methods: Methods for Linear Systems, Least Squares, Householder's Tridiagonalization and QR-Factorization, Methods for Elliptic, Parabolic, Hyperbolic PDEs **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 **Module-9:** Optimization and Linear Programming: Method of Steepest Descent, Linear Programming, Fundamental theorem of linear inequalities, Cones, polyhedral. and polytopes, Farkas' lemma, LPduality, max-flow min-cut, Simplex Method, primal dual, Fourier-Motzkin elimination, relaxation methods **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. **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, Pearson Education, 2006. **5.** A. Schrijver, Theory of Linear and Integer Programming, 1998. **6.** D.S. Dummit, R.M. Foote, Abstract Algebra, 2004.

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1	**Title of the course** (L-T-P-C)	**Mathematics for Data Science** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to basic concepts in calculus and linear algebra
3	**Course content**	Introduction to Data science and Motivation for the course. Review of calculus, naTve set theory, notion of limits, ordering, series, and its convergence. Introduction to Linear Algebra in Data science, notion of vector space, dimension and rank, algorithms for solving linear equations, importance of norms and notion of convergence, matrix decompositions and its use. Importance of optimization in data science: Birds view of Linear Regression, Multivariate Regression, Logistic Regression etc. Convex Optimization: Convex sets, convex functions, duality theory, different types of optimization problems, Introduction to linear program. Algorithms: Central of gravity method, Gradient descent methods, Nestrov acceleration, mirror descent/ Nestrov dual averaging, stochastic gradient methods, Rmsprop, SIGNSGD, ADAM algorithm etc. Non-convex optimization: Demonstration of convex methods on non-convex problems; merits and disadvantages.
4	**Texts/References**	C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006. • Cambridge university press, 2018 (reprint). for Machine Learning," Now publisher, 2017.

Engineering and Applied Mathematics basket of courses: (minimum 6 credits)

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Numerical Linear Algebra** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Calculus, Linear Algebra
3	**Course content**	Vector and Matrix Norms, Gram Schmidt Orthogonalization, Singular Value Decomposition, QR factorization, Householder Triangularization Floating point number system, Condition number and Stability, Stability of Back substitution, Gauss Elimination and Householder methods Numerical techniques for finding eigenvalues, Rayleigh Quotient, QR methods, Divide and Conquer strategies. Krylov subspace techniques, GMRES and Conjugate Gradient
4	**Texts/References**	**1.** Lloyd N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, US, 1997 **2.** Gene Golub and Charles Van Loan, Matrix Computations, 4^{th} Edition, John Hopkins University Press, US, 2013 **3.** Iterative Methods for Sparse Linear Systems, Youse fnd Saad, 2 Edition, SIAM, US, 2003

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1	**Title of the course** (L-T-P-C)	**Introduction to Numerical Methods** **(3-1-0-4)**
2	**Pre-requisite courses(s)**	Calculus, MA101 & Linear Algebra, MA 106
3	**Course content**	Interpolation by polynomials, divided differences, error of the interpolating polynomial, piecewise linear and cubic spline interpolation. Numerical integration, composite rules, error formulae. Solution of a nonlinear equation, bisection, and secant methods. Newton's method, rate of convergence, solution of a system of nonlinear equations, Numerical solution of ordinary differential equations, Euler and Runge-Kutta methods, multi-step methods, predictor-corrector methods, order of convergence, Finite difference methods, numerical solutions of elliptic, parabolic, and hyperbolic partial differential equations. Exposure to MATLAB
4	**Texts/References**	S. D. Conte and Carl de Boor, Elementary Numerical Analysis- An Algorithmic Approach (3rd Edition), McGraw-Hill, 1980

Programming and Scientific Computing basket of courses: (minimum 5 credits)

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Topics in Data Structures and Algorithms** **(2-0-2-6)**
2	**Pre-requisite courses(s)**	No prerequisites
3	**Course content**	Data structures - arrays, linked lists, stacks and queues, heap, and binary search tree. Algorithm design techniques - divide and conquer, greedy, and dynamic programming. Algorithms for graph problems. Asymptotic notations, Complexity lower bounds and NP-completeness.
4	**Texts/References**	**Textbook:** **a)** Cormen, Leiserson, Rivest and Stein, **Introduction to Algorithms**, 3rd edition, by, MIT Press, 2009. **Reference:** **b)** Sanjoy Dasgupta, Christos Papadimitriou and Umesh Vazirani, **Algorithms**, McGraw Hill Education, 2008. **c)** Kleinberg and Tardos, **Algorithm Design**, 1st edition, Pearson, 2006.

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1	**Title of the course** (L-T-P-C)	**Programming Parallel Machines** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Good programming experience in C, C++, or Fortran.
3	**Course content**	Elements of parallel algorithm design (domain decomposition, mapping), Parallel hardware architecture - overview of shared-memory systems, cache coherence, and sequential consistency. Shared- memory programming (OpenMP, PThread, Cilk). Scalable algorithm design and measuring performance (speedup, efficiency). Distributed-memory programming (MPI and message-passing model, global address space model). Interconnects. Introduction to GPU programming.
4	**Texts/References**	**1.** Ananth Grama, Anshul Gupta, George Karypis, Vipin Kumar: Introduction to Parallel Computing, Addison Wesley 2003 **2.** https://computing.llnl.gov/tutorials/mpi/ **3.** https://computing.llnl.gov/tutorials/open MP/

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1	**Title of the course** (L-T-P-C)	**Software Development for Scientific Computing (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Data Structures and Algorithms, C / C++ / Java / MATLAB
3	**Course content**	Algorithmic Patterns in Scientific Computing: dense and sparse linear algebra, structured and unstructured grid methods, particle methods (N-body, Particle-Particle, Particle-in-cell, Particle-in-a- mesh), Fast Fourier Transforms, Implementing PDEs, C++ standard template library (STL), Introduction to debugging using GDB, GMake, Doxygen, Version Control System, Profiling and Optimization, asymptotic analysis, and algorithmic complexity. Mixed-language programming using C, Fortran, MATLAB, and Python, Performance analysis and high-performance code, Data locality and auto tuning, Introduction to the parallel programming world.
4	**Texts/References**	• Stroustrup C++ Language Reference (https://www.stroustrup.com/4th.html) • Suely Oliveira, David Steward: Writing Scientific Software: A Guide to Good Style. Cambridge University Press, 2006 • Web references to GNU Make, GDB, Git, GProf, Gcov. • Code Complete: A Practical Handbook ofSoftware Construction • https://www2.eecs.berkeley.edu/Pubs/TechRpts/2006/EECS -2006-183.html

List of already approved PG electives:

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<table>
<tr><td>1</td><td>Title of the course
(L-T-P-C)</td><td>Advanced Finite Element Methods
(3-0-0-6)</td></tr>
<tr><td>2</td><td>Pre-requisite courses(s)</td><td>Finite Element Methods</td></tr>
<tr><td>3</td><td>Course content</td><td>FEM formulation for time dependent problems (16 hours)
- Transient heat transfer problems
- Structural dynamics problem
- Explicit and Implicit methods of solutions
- stability, accuracy, and convergence study of solution methods

Introduction to reduced order modelling technique: (6 hours)
- Introduction to reduced order modeling
- Methods of reduced order modeling
o Static condensation,
o mode superposition,
o component mode synthesis,
o Krylov subspace technique.

Nonlinear Finite Element Method (18 hours)
- Introduction to Nonlinear FEM
- FEM for geometric nonlinearity and forcing nonlinearity,
- FEM for elastic-plastic analysis
o Strain hardening model.
o Kinematic hardening model
- Methods to solve nonlinear problems.
o Newton Raphson method
o Secant method
o Continuation method
- Convergence of nonlinear solutions
o Force convergence. Displacement convergence</td></tr>
<tr><td>4</td><td>Texts/References</td><td>1. J.N. Reddy, Introduction to Finite Element Method, Tata McGraw-Hill, 2006
2. J. N. Reddy, An Introduction to Nonlinear Finite Element Analysis, Oxford University Press, 2004.
3. K. J. Bathe, Finite Element Procedures, PHI Learning Pvt. Ltd., 1996
4. T. J. R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Dover Publications, 2000
5. Zu-Qing Qu, Model Order Reduction Techniques with Applications in Finite Element Analysis, Springer, 2004</td></tr>
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1	**Title of the course** (L-T-P-C)	**Advanced Heat Transfer** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nill
3	**Course content**	**Module-1: Conduction:** Equations and boundary conduction in different coordinate systems; Analytical Solutions: separation of variables, Laplace Transform, Duhamel's theorem: Non-impulse initial conditions; Numerical Methods: Finite difference and flux conservation; Interfacial heat transfer. **Module-2: Convection:** Conservation equations and boundary conditions; Heat transfer in laminar developed and developing boundary layers: duct flows and external flows, analytical and approximate solutions, effects of boundary conditions; Heat transfer in turbulent boundary layers and turbulent duct flows; Laminar and turbulent free convection, jets, plumes and thermal wakes, phase change. **Module-3: Radiation:** Intensity, radiosity, irradiance, view factor geometry and algebra; formulations for black and non–black surfaces, spectrally–selective surfaces (solar collectors); Monte Carlo methods for radiation exchange; The radiative transfer equation, extinction and scattering properties of gases and aerosols, overview of solution methods and applications. **Module-4: Interaction between conduction, convection, and radiation:** Coupled problems; Examples in manufacturing and electronic cooling applications; Micro channels and micro fins.
4	**Texts/References**	**1.** M N Ozisik, Heat Conduction, 2nd ed, John Wiley & Sons, 1993. **2.** Kakaç, S., Yener, Y., Heat Conduction, 3rd edition, Taylor & Francis, 1993. **3.** F P Incropera and D P Dewitt, Introduction to Heat Transfer, 3rd ed, John Wiley & Sons, 1996. **4.** W. M. Kays and E. M. Crawford, Convective Heat and Mass Transfer, Mc Graw Hill,1993. **5.** Adrian Bejan, Convective Heat Transfer, John Wiley, and Sons, 1995. **6.** M F Modest, Radiative Heat Transfer, McGraw-Hill, 1993. **7.** R Siegel and J R Howell, Thermal Radiation Heat Transfer, 3rd ed, Taylor & Francis, 1992.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Combustion and Fire Dynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Fundamentals** Motivation for studying combustion, Fuels, and their combustion properties: diesel, gasoline, aviation fuels, natural gas, coal, Thermochemistry: the composition of a gas mixture: mass and mole fraction, Chemical reactions –theoretical and actual combustion processes, Enthalpy of formation and enthalpy of combustion, Adiabatic flame temperature, Introduction to mass transfer, Chemical equilibrium. Chemical kinetics – reaction rates, chemical time scales. **Flames** Conservation equations with chemical reaction, Laminar premixed flames – flame speed, governing equations, flammability limits, flame stability, Laminar diffusion flames – diffusive burning of liquids, stagnation layer model – pure convective burning, radiative convective burning, Droplet evaporation and burning – Spalding number. **Measurement in Fire** Measurement of temperature – thermocouples, plate thermometer for the measurement of temperature and heat flux, heat flux sensors, cone calorimetry, measurement of soot volume fraction, soot yield and spectral measurements. **1. Introduction to Numerical Fire Simulations** Governing equations–hydrodynamics model, combustion model,radiation model, solution algorithm, simulation of typical fires.
4	**Texts/References**	**1.** Stephen R. Turns, An Introduction to Combustion: Concepts and Applications, Third edition, McGraw Hill Education (India) Private Limited, New Delhi, 2012. **2.** James G. Quintiere, Fundamentals of Fire Phenomena, John Wiley and Sons, Wet Sussex, 2006. **3.** The SFPE Handbook of Fire Protection Engineering, fourth edition, National Fire Protection Association (NFPA), Massachusetts, 2008.

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1	**Title of the course** (L-T-P-C)	**Convective Heat Transfer** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Flow classifications, mass momentum and energy relation in differential form. Exact and approximate solution to convection in laminar and turbulent, internal, and external flow. solution to natural convection problems.
4	**Texts/References**	**1.** kays w, Crawford M, Wigand B., connective Heat, and mass Transfer Fourth Edition McGraw Hill Education, 2017 **2.** sodic kakac and Yamane yenar, connective Heat Transfer, Second Edition, CRC Press 1994 **3.** Louis C Burmiester, connective Heat Trasfer Second Edition, john wily and sons 1993 **4.** Bejan A, connective Heat Transfer Third Edition, wily,2006 **5.** Kavinay M, Principles of connective heat transfer, second Edition springer,2001.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Design of Mechatronic Systems** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	Introduction: Elements of mechatronics system: Sensor, actuator, plant, and controller. Applications of mechatronics system. Systems like CDROM, scanner opened to see what's there inside and why? Integrated mechanical-electronics design philosophy. Examples of real-life systems. Smart sensor concept and utility of compliant mechanisms in mechatronics. Microprocessor building blocks, combinational and sequential logic elements, memory, timing, and instruction execution fundamentals with example of primitive microprocessor. Microcontrollers for mechatronics: Philosophy of programming interfaces, setting sampling time, and getting started with TIVA programming. Microcontroller programming philosophy emphasis on TIVA, programming different interfaces PWM, QEI etc. Mathematical modeling of mechatronic systems, Modeling friction, DC motor, Lagrange formulation for system dynamics. Dynamics of 2R manipulator, Simulation using Matlab, Selection of sensors and actuators. Concept of feedback and closed loop control, mathematical representations of systems and control design in linear domain, Basics of Lyapunov theory for nonlinear control, notions of stability, Lyapunov theorems and their application Trajectory tracking control development based on Lyapunov theory, Basics of sampling of a signal, and signal processing. Digital systems and filters for practical mechatronic system implementation. Research example/ case studies of development of novel mechatronics system: 3D micro-printer, Hele Shaw system for microfabrication.
4	**Texts/References**	• Devdas Shetty, Richard A. Kolk, "Mechatronics System Design," PWS Publishing company. • Boukas K, Al-Sunni, Fouad M "Mechatronic, Systems Analysis, Design and Implementation," Springer, • Sabri Cetinkunt, "Mechatronics with Experiments," 2nd Edition, Wiley • Janschek, Klaus, "Mechatronic Systems Design," Springer

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Fatigue and Fracture Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Strength of Materials/Mechanics of Materials (& Theory of Elasticity)
3	**Course content**	**Module 1(10 hours):** Introduction and historical overview, Types of fatigue –low cycle fatigue, high cycle fatigue, very high cycle (giga cycle) fatigue, Fatigue test methods and equipment, Total life approaches based on cyclic stress and cyclic strain, Cyclic hardening and softening in single crystals and polycrystals. **Module 2(10 hours):** Crack initiation and propagation, Mechanisms, Macro-structural and microstructural aspects, Use of fracture mechanics in fatigue **Module 3(10 hours):** Local strain approach, effect of different factors on fatigue–Stress concentration, Size, Surface, Temperature, Frequency, Environment, Microstructure, Residual stresses, Fretting, Creep-fatigue interaction, Multiaxial stresses, Thermomechanical loading, Variable amplitude loading, Load sequence, Crack closure. **Module 4(10 hours):** Fatigue behavior of different materials – Metallic materials and weldments, Ceramics, Polymers, Composites, Metallic glasses, Shape memory alloys, Ultrafine grained materials, Nanocrystalline materials, Biomaterials, Metallic foams, Case studies on fatigue failures, Design considerations, Methods for fatigue life improvement
4	**Texts/References**	**1.** Fatigue of Materials, Suresh, Cambridge India, 2015 **2.** Fracture Mechanics, Fundamentals and Applications, T.L. Anderson, CRC Press 2017

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Fluid Flow and Heat Transfer in Porous Media (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to fluid mechanics and heat transfer
3	**Course content**	**Module 1:** Mechanics of Fluid flow through Porous Medium: porosity, volume averaging procedure, Equation of continuity, momentum equation (Darcy's Law, Forchheimer equation, Brinkman equation), Turbulence in porous media. (10 hr) **Module 2:** Heat Conduction in Porous Medium: Local thermal equilibrium, effective stagnant thermal conductivity, thermal dispersion, local thermal non-equilibrium, interfacial heat transfer coefficient (8 hr) **Module 3:** Forced Convection through Porous Medium: external flow, internal flows, and jet impinging flows (9 hr) **Module 4:** Natural Convection through Porous Medium: external flows (9 hr) **Module 5:** Radiation heat transfer through Porous Medium: Radiation transport equation, energy equation with radiation (6 hr)
4	**Texts/References**	**1.** Donald A Nield and Adrian Bejan, Convection in Porous Medium, Springer publications, Newyork, 2017, Fifth Edition. **2.** M. Kaviany, Principles of Heat Transfer in Porous Media, Springer publications, Newyork, 1999, Second Edition **3.** Arunn Narasimhan, Essentials of Heat and Fluid Flow in Porous Media, Ane Books Private Limited, New Delhi, 2016, First Edition. **4.** Faruk Civan, Porous Media Transport Phenomena, John Wiley and Sons, Singapore, 2011, First Edition. **5.** F.A. L. Dullien, Porous Media: Fluid Transport and Pore Structure, Academic Press, London, 1992, Second Edition. **6.** Kambiz Vafai, Handbook of Porous Media, Taylor and Francis, Florida, 2005, Second Edition.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Fracture Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Theory of Elasticity or equivalent
3	**Course content**	**Module 1: Background** Kinds of Failure; Historical Aspects; Brittle and Ductile Fracture; Modes of Fracture Failure **Module 2: LEFM** Griffith's Theory of Brittle Fracture; Irwin-Orowan Modification; Stress Intensity Factor (SIF) Approach; Concepts of Strain Energy and Potential Energy Release Rates; Determination of Crack-Tip Stress and Displacement Field - Airy Stress Function Approach, Westergaard Stress Function Approach, Williams' Eigenfunction Expansion. Determination of Stress Intensity Factors: Analytical Methods, Numerical and Experimental Methods. Mixed Mode Brittle Fracture: Theory based on Potential Energy Release Rates, Maximum Tangential Stress Criterion, Maximum Tangential Principal Stress Criterion, Strain Energy Density Criterion **Module 3: Anelastic Deformation at Crack Tip** Irwin Plastic Zone Size Correction; Dugdale-Barenblat Model for Plastic Zone Size; Crack-Tip Mode I, II and III Plastic Zone Shape; Thickness Dependence of Fracture Toughness KC; Crack Opening Displacement; Rice's Path-Independent Integral J; Resistance Curve; Stability of Crack Growth **Module 4: Elastic Plastic Fracture Mechanics** Crack Opening Displacement Criterion: Mode I Crack-Tip Field - Rice-Rosengren Analysis, Hutchinson's Analysis; Crack-Tip Constraints: T Stress and Q Factor; Crack Propagation and Crack Growth Stability **Module 5: Fatigue Crack Growth** Fatigue Crack Growth Rate under Constant Amplitude Loading; Factors Affecting Fatigue Crack Propagation; Crack Closure; Life Estimation Using Paris Law; Variable Amplitude Cyclic Loading **Module 6: Experimental Measurement of Fracture Toughness Data** Measurement of Plane Strain Fracture Toughness KIC, Critical COD δC, K-Resistance Curve - Linear Elastic Material and Elastic Plastic Material
4	**Texts/References**	**<u>Textbooks:</u>** **1.** T. L. Anderson, Fracture Mechanics: Fundamentals and Applications, 4th ed. – Boca Raton 2017. **2.** D. Broek, Elementary Engineering Fracture Mechanics, 3rd Revised Edition, Springer Netherlands, 1982, **3.** Maiti S.K, Fracture Mechanics: Fundamentals and Applications. – 1st Edition, Delhi: Cambridge University Press, 2015. **<u>References:</u>** **1.** Prashant Kumar, Elements of Fracture Mechanics, Tata McGraw-Hill. Education, 2009, **2.** CT Sun, Fracture Mechanics, Academic press, 2012, **3.** T. Kundu, Fundamentals of Fracture Mechanics, CRC Press, 2008.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Fundamentals of Acoustics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Fluid Mechanics
3	**Course content**	**Review of classical acoustics**: review of classical acoustics, linearized equations of motion, classical wave equation. Speed of sound, harmonic waves, acoustic energy/intensity, decibel scale. Acoustic impedance and admittance, reflection, and transmission at the interface of two media, Impedance tube technique. **Sound propagation:** plane and spherical waves, Travelling and standing waves, boundary conditions, Eigen frequency and Eigen modes. Effects of area variation, reflection, and transmission of waves in pipes. Acoustic wave propagation in homogeneous and inhomogeneous media. **Models for acoustic sound sources:** point sources, monopoles, dipoles, and quadrupoles, **Aero-acoustic sources:** Lighthill's acoustic analogy, integral solutions, and far-field approximations; effect of solid surface. **Losses:** Viscous and thermal conduction losses, absorption coefficient, sound absorption in pipes **Measurement** of sound signals, microphones, time series analysis using Fast Fourier Transform, Discrete Fourier Transform, Transfer function, and Bode plots. Solving numerical problems. **Applications to engineering problems**: Aero-acoustic jet noise, Thermoacoustic instability, fan/rotor noise and numerical evaluation
4	**Texts/References**	1. Lawrence E. Kinsler, Austin R. Frey, and Alan B. Coppens, 2000. Fundamentals of acoustics. 4th edn. John-Wiley & Sons, Inc. 2. **Pierce, Allan D. Acoustics: an introduction to its physical principles and applications. Springer, 2019.** 3. **Munjal, M. L. (1987). Acoustics of ducts and mufflers with application to exhaust and ventilation system design. John Wiley & Sons.** 4. **Tim C. Lieuwen, 2012. Unsteady combustor physics. 1st edn. Cambridge University Press.**

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Fundamentals of Tribology** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nill
3	**Course content**	**Introduction – Materials and surfaces:** Tribology — Historical perspective, Industrial Significance, Economic considerations; Solid structure and properties — Atomic Structure, Bonding and Coordination, Disorders in Solid Structures, Elastic and Plastic Deformation, Fracture and Fatigue, Time Dependent Viscoelastic & Viscoplastic Deformation. Surfaces — Nature of surfaces, Characteristics of Surface Layers, Surface texture, Surface parameters, Measurement of surface parameters, Statistical properties of surfaces, Analysis of Surface Roughness. **Contacts:** Analysis of Contacts — Single Asperity, Multiple Asperity Contacts, Measurement of the Real Area of Contact, Stress distribution, Displacements due to loading, Hertzian and non-Hertzian contacts, rough surfaces in contact, Deformation mode, Thermal effects; Adhesion — Solid–Solid Contact, Contact with liquid mediation. **Friction:** Friction — Measurement, Causes, Theories, Plastic interaction of surface asperities, ploughing effect, Elastic hysteresis losses, Solid–Solid Contact, Liquid-Mediated Contact, Friction of Materials; Rolling Motion — Free rolling, Microslip in rolling, Tyre-road contacts. **Wear:** Wear — Definitions, Mechanisms, Wear Debris, Wear of Materials, Indentation cracking, Factors affecting wear, Experimental considerations, Wear control, Application of wear in design, Characteristics of friction induced vibrations. **Lubrication:** Lubricants — Viscosity, Measurement of viscosity, Lubricating oils, Greases; Lubrication — Regimes of Fluid Film Lubrication, Viscous Flow and Reynolds Equation, Hydrostatic Lubrication, Hydrodynamic Lubrication, Elasto-hydrodynamic Lubrication.
4	**Texts/References**	**1.** Introduction to Tribology, Bharat Bhushan, John Wiley & Sons. **2.** Principles of Tribology, Halling, J. (Ed), Macmillan, 1975.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Introduction to Turbulence and its Modelling** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	ME203 Fluid Mechanics.
3	**Course content**	• **Introduction to Turbulence**: Nature of turbulence, origin of turbulence, laminar and turbulent boundary layers, diffusion of turbulence, concept of eddy viscosity • **Statistics of Turbulence**: Statistical aspects of turbulence, scales in turbulence, spectrum of turbulence, energy cascade in isotropic turbulence, Kolmogorov hypotheses • **Mathematical Theory of Turbulence**: The Reynolds equation, Reynolds decomposition, equations for the mean flow, Reynolds stress, mixing length model, turbulent heat transfer, limitations of mixing length theory • **Dynamics of Turbulence**: Dynamics of turbulence, Taylor microscale, Reynolds stress and vorticity, the vorticity equation • **Boundary-free and Wall-bounded Turbulence**: Turbulent wakes, turbulent jets and mixing layers, turbulent flows in pipes and channels, experimental techniques for turbulence characteristics. • **Introduction to Turbulence Modelling**: Turbulence modelling and closure problem, algebraic models, modern variants of the mixing length model, one equation models, k-□ and k-□ models, Spalart–Allmaras turbulence model • **Introduction to Numerical Techniques for Turbulence**: Direct numerical simulations (DNS), large eddy simulations (LES) and Reynolds averaged Navier-Stokes (RANS) modelling techniques, spectral methods, and particle-based methods for turbulence
4	**Texts/References**	**TEXTBOOKS** **1.** Tennekes H. and Lumley J., A first course in turbulence, M.I.T. Press. **2.** Tritton D.J., Physical Fluid Dynamics, Oxford University Press. **3.** Davidson P.A., Turbulence: An Introduction for Scientists and Engineers, Oxford Uni Press. **4.** Townsend A.A., The structure of turbulent shear flow, Cambridge University Press., 1980. **5.** Wilcox D.C., Turbulence modeling for CFD, DCW Industries, Incorporated, 1994.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Mechanical Vibrations** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Module 1:** Concepts of Vibrations: Harmonic motion and definitions and terminology, Harmonic analysis, Fourier series expansion, Importance of vibration, Basic concepts of vibration, Classification of Vibration, Vibration analysis procedure; Discrete System Components – Springs, Dampers and Masses. **Module 2:** One DOF systems: Free Vibrations, Harmonic Oscillator, Types of damping, Viscously Damped Single DOF Systems, Measurement of Damping, Coulomb Damping – Dry Friction. Forced Vibrations – Response of Single DOF System to Harmonic Excitations, Response to Periodic Excitations, Response of Single DOF systems to Nonperiodic Excitations. **Module 3:** Two DOF Systems: System Configuration, Equations of Motion of 2 DOF Systems, Free Vibration of Undamped Systems Natural Modes, Response to Initial Excitations, Coordinate Transformations – Coupling, Orthogonality of Modes - Natural Coordinates, Beat Phenomenon, Response of Two-Degree-of-Freedom Systems to Harmonic Excitations, Undamped Vibration Absorbers. **Module 4:** Vibrations of Continuous Systems: Vibrating String, Longitudinal vibrations of Bar, Torsional vibrations of Rod. Lateral vibrations of Beam. Analytical Dynamics: Degrees of Freedom and Generalized Coordinates, Principle of Virtual Work, Principle of D'Alembert, Hamilton's Principle, Lagrange's Equations. **Module 5:** Multi-Degree-of-Freedom Systems: Equations of Motion for Linear Systems; Flexibility, Stiffness Influence Coefficients and Mass Coefficients; Lagrange's Equations; Linear Transformations; The Eigenvalue Problem; Orthogonality of Modal Vectors; Systems Admitting Rigid-Body Motions; Decomposition of the Response in Terms of Modal Vectors; Response to Initial Excitations by Modal Analysis; Eigenvalue Problem in Terms of a Single Symmetric Matrix; Geometric Interpretation of the Eigenvalue Problem; Rayleigh's Quotient and Its Properties; Response to Harmonic External Excitations; Response to External Excitations by Modal Analysis – Undamped systems, Systems with proportional damping; Systems with Arbitrary Viscous Damping; Discrete-Time Systems. .
4	**Texts/References**	**Textbooks:** **1.** S S Rao, Mechanical Vibrations, Pearson Education, 5 th Edition, 2004. **References:** **1.** W T Thomson, M D Dahleh and C Padmanabha, Theory of Vibration with applications, Pearson Education, 2008. **2.** Leonard Meirovitch, Fundamentals of Vibrations, McGraw-Hill, 2000. Den Hartog, Mechanical Vibrations, Dover Publications, 4 th Edition.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Linear Viscoelasticity** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Concepts of Viscoelasticity** – Force-extension equations of the simple models, Creep and relaxation behavior, Complex modulus, and compliance, Stored and dissipated energies, Creep and relaxation behavior of some real materials. **Fundamental Aspects of Viscoelastic Response** – Introduction, Nature of Amorphous Polymers, Mechanical Response of Viscoelastic Materials, Energy Storage and Dissipation, Glass Transition and Regions of Viscoelastic Behavior, Aging of Viscoelastic Materials. **Constitutive Equations in Hereditary Integral Form** – Boltzmann's Superposition Principle, Principle of Fading Memory, Closed-Cycle Condition, Relationship Between Modulus and Compliance, Alternate Integral Forms, Work and Energy. **Constitutive Equations in Differential Operator Form** – Fundamental Rheological Models, Rheological Operators, Construction of Rheological Models, Simple Rheological Models, Generalized Models, Composite Models. **Constitutive Equations for Steady-State Oscillations** – Steady-State Constitutive Equations from Integral Constitutive Equations, Steady-State Constitutive Equations from Differential Constitutive Equations, Limiting Behavior of Complex Property Functions, Energy Dissipation. **Structural Mechanics** – Bending, Torsion, Column Buckling, Viscoelastic Evens, Elastic– Viscoelastic Correspondence, Mechanical Vibrations. **Thermoviscoelasticity** – Thermodynamical Derivation of Constitutive Relations, Restrictions and Special Cases, Time Temperature Superposition, Relationship to Nonnegative Work Requirements, Formulation of the Thermoviscoelastic Boundary Value Problem, Temperature Dependence of Mechanical Properties, Thermorheologically Simple Materials, Phenomenology of the Glass Transition, Glass Transition Criterion, Effect of Pressure on the Glass Transition Temperature, Hygrothermal Strains, Heat Conduction.
4	**Texts/References**	**1.** Engineering Viscoelasticity, Gutierrez-Lemini, Danton, Evener, 2014. **2.** Theory of Viscoelasticity, R. M. Christensen, 2nd Edition, Dover Civil and Mechanical Engineering. **3.** The Theory of Linear Viscoelasticity, D. R. Bland, Dover Books on Physics. **4.** Viscoelasticity of Engineering Materials, Haddad, Y.M., Evener, 1995.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Mechanics of Composite Materials (3-0-0-6)**
2	**Pre-requisite courses(s)**	Mechanics of Materials
3	**Course content**	**Module 1: Basic Concepts, Materials, Processes and Characteristics**: Conventional materials and composite materials; Terminologies definition; composite materials Classification; Scales of analysis and basic lamina properties; Constituent Materials Manufacturing methods **Module 2: Lamina's elastic and strength behavior - Micromechanics**: Micromechanics model; Longitudinal and transverse elastic properties of continuous fibers; In-plane shear modulus; Longitudinal properties of discontinuous fibers or short fibers – Shear lag analysis; Strength – longitudinal tensile and compressive behavior, transverse tensile and compressive behavior, in- plane shear, pout-of-plane behavior **Module 3: Lamina's elastic and strength behavior - Micromechanics**: Stress-strain relation – Anisotropic; orthotropic, transversely isotropic, and isotropic; Stress-strain relations for a lamina; Transformations- stress, strain elastic moduli in 2D and 3D; Failure theories – Maximum stress, maximum strain, Tsai-Hill; Failure-mode-based theories. **Module 4: Multi-directional Laminate's elastic and strength behavior**: Strain-displacement relations; Stress-strain relation; Laminate's stiffness/compliance; Types of laminates – symmetric, balanced, orthotropic and quasi-isotropic laminates; Determination of elastic parameters for uni- directional and angle-ply laminates; Modified lamination theory for transverse shear; Strength – types of failure, stress analysis and strength component for first-ply failure of symmetric laminates; Extension to multidirectional laminates; Carpet plots **Module 6: Bending, Buckling, And Vibration of Laminated Plates**: governing equations for bucklion, vending and vibrations; flexural deflection of simply supported laminated plates; buckling of simply supported laminated plates; vibration of simply supported laminated plates. **Module 7: Hygrothermal effects**: Introduction, CoTE (thermal expansion) and CoME (Moisture- expansion) for a lamina; Load-deformation relations in hygrothermalelasticity; COTE and COME for multi-directional laminates; Warpage and residual stresses; Effect on strength of mechanical and hygrothermal loading on multi-directional laminates. **Module 8: Experimental characterisation and testing of Composite materials:** Characterisation of constituent materials; Determination of tensile/compressive and shear properties of uni-directional laminae; Through thickness properties; Biaxial testing; Stress concentration characterization and structural testing.
4	**Texts/References**	**Textbooks:** 1. M. Daniel and O. Shai, Engineering Mechanics of Composite Materials, 2nd ed., Oxford University Press.

		2. R. M. Jones, Mechanics of Composite Materials, 2nd Ed., CRC Press. **References:** **1.** Kaw, Mechanics of Composite Materials, 2nd Ed., CRC Press., **2.** V.V. Vasiliev and E.V. Morozov, Mechanics and Analysis of Composite Materials, Elsevier, 2001. **3.** R.M. Christensem, Mechanics of Composite Materials, Dover**,** **4.** H. Altenbach, J. Altenbach, W. Kissing, Mechanics of Composite Structural Elements, Springer-Verlag Berlin Heidelberg, 2004Reference: **5.** Parameterized Complexity, R. G. Downey, and M. R. Fellows. Springer Science and Business Media. 2012

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Metal Forming and Plasticity** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Manufacturing Science
3	**Course content**	**Introduction:** Different metal forming processes, importance of plasticity in the course. **Module 1:** Analysis of stress: transformation relations, principal stresses and directions, maximum normal and shear stresses, invariants, hydrostatic and deviatoric parts; Analysis of (infinitesimal) strain: transformation relations, principal strains, invariants, hydrostatic and deviatoric parts; (Infinitesimal) rotation, Stress strain relations for isotropic, linearly elastic material. **Module 2:** Experimental observations on plasticity: yielding, strain hardening, viscos plasticity, temperature softening, Baushinger effect, hysteresis, incompressibility of plastic deformation, anisotropy, plastic instability. **Module 3:** Yield criterion for isotropic materials: von Mises and Tresca yield criterion, their geometric interpretation, convexity of the yield surfaces, experimental validation. **Module 4:** Incremental and rate forms of the measures of plastic deformation: linear incremental strain tensor, strain rate (i.e. the rate of deformation) tensor and their relation, incremental rotation tensor and spin tensor. **Module 5:** Change in yield criteria due to isotropic hardening: strain hardening and work hardening hypotheses, experimental validation of the hypotheses. **Module 6:** Plastic stress strain relations for isotropic materials: plastic potential and associated flow rule, incremental and rate forms of elastoplastic stress strain relations, simplifications for non- hardening and rigid plastic materials (Prandtl Reuss and Levy-Mises's relations), Objective measures of stress rate and incremental stress.
4	**Texts/References**	**1.** The Mathematical Theory of Plasticity by R. Hill, Oxford University Press **2.** Theory of Plasticity by J. Chakrabarty, Butterworth-Heinemann, 3rd edition **3.** Metal Forming Mechanics and Metallurgy, William F. Hosford, Robert M. Caddell Cambridge University Press; 4th edition.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Nonlinear Solid Mechanics for Finite Element Method (3-0-0-6)**
2	**Pre-requisite courses(s)**	Solid Mechanics and Finite Element is recommended
3	**Course content**	**1. Introduction to Tensors:** Overview of conventions & mathematical identities in vector calculus and tensor algebra **2. Review of Linear Elasticity:** Linear strain tensor, compatibility conditions, stress tensor, equilibrium equation **3. Kinematics of Deformation:** Material and spatial derivatives, Deformation gradient, Strain tensor, Velocity gradients, Spin tensor, Lie time derivatives. **4. Concept of Stress:** Cauchy stress theorem, Piola transformation, First Piola-Kirchhof (PK) stress, Principal directions, Alternative stress definitions such as Second PK stress, Biot stress, Corrotated Cauchy stress tensors **5. Balance Principals and Constitutive relation:** Conservation of mass, Reynolds' Transport theorem, Principals of Momentum and Energy balance **6. Hyper elasticity:** Various strain-energy constitutive formulations - invariant based model, isotropic model, incompressible model, composite material model, examples from the field of soft tissue biomechanics and tyre industry **7. Viscoelasticity:** Generalized Maxwell Model, Relaxation time **8. Finite Element for Non-linear material:** Variational Principles, Objective stress rates, Linear Consistent Tangent Modulus, numerical challenge due to incompressibility
4	**Texts/References**	**<u>Textbooks:</u>** **1.** Gerhard A. Holzapfel, Non-linear Solid Mechanics- A continuum approach for engineering, John Wiley, and Sons Ltd. 2000. **<u>References:</u>** **2.** J. Bonet, RD. Wood, Non-linear Continuum Mechanics for Finite Element Analysis (2nd Ed), Cambridge University Press., 2008. **3.** LA. Taber, Non-linear Theory of Elasticity – Applications in Biomechanics, World Scientific Publishing, 2004. **4.** Rene de Borst, Mike A. Crisfield, Joris J.C. Remmers, and Clemens V. Verhoosel, Non-linear Finite Element Analysis of Solid and Structures, (2nd Edition), John Wiley and Sons Ltd., 2012.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Turbomachinery Aerodynamics (3-0-0-6)**
2	**Pre-requisite courses(s)**	Thermodynamics, Fluid Mechanics during UG
3	**Course content**	**Introduction to Turbo machineries** **Axial flow compressors and Fans:** Introduction; Aero-Thermodynamics of flow through an Axial flow Compressor stage; Losses in axial flow compressor stage; Losses and Blade performance estimation; Secondary flows (3-D); Tip leakage flow and scrubbing; Simple three dimensional flow analysis; Radial Equilibrium Equation; Design of compressor blades; 2-D blade section design: Airfoil Data; Axial Flow Track Design; Axial compressor characteristics; Multi-staging of compressor characteristics; Transonic Compressors; Shock Structure Models in Transonic Blades; Transonic Compressor Characteristics; 3-D Blade shapes of Rotors and Stators; Instability in Axial Compressors; Loss of Pressure Rise; Loss of Stability Margin; Noise problem in Axial Compressors and Fans **Axial flow turbines:** Introduction; Turbine stage; Turbine Blade 2-D(cascade) analysis Work Done; Degree of Reaction; Losses and Efficiency; Flow Passage; Subsonic, transonic, and supersonic turbines, Multi-staging of Turbine; Exit flow conditions; Turbine Cooling; Turbine Blade design – Turbine Profiles: Airfoil Data and Profile construction. **Centrifugal Compressors:** Introduction; Elements of centrifugal compressor/ fan; Inlet Duct Impeller; Slip factor; Concept of Rothalpy; Modified work done; Incidence and lag angles; Diffuser; Centrifugal Compressor Characteristics; Surging; Choking; Rotating stall; Design. **Radial Turbine:** Introduction; Thermodynamics and Aerodynamics of radial turbines; Radial Turbine Characteristics; Losses and efficiency; Design of radial turbine. Use of CFD for Turbomachinery analysis and design.
4	**Texts/References**	**1.** Dixon, S. Larry, and Cesare Hall, "Fluid mechanics and thermodynamics of turbomachinery," Butterworth-Heinemann, 2013. **2.** Lakshminarayana, Budugur, "Fluid dynamics and heat transfer of turbomachinery," John Wiley & Sons, 1995. **3.** Cumpsty, Nicholas A., "Compressor aerodynamics," Longman Scientific & Technical, 1989. **4.** Hill, Philip G., and Carl R. Peterson, "Mechanics and thermodynamics of propulsion," AW (1992). **5.** Johnsen, Irving A., and Robert O. Bullock, eds., "Aerodynamic Design of Axial-Flow Compressors," NASA SP-36, 1965. **6.** Glassman, Arthur J., ed., "Turbine design and application," NASA-SP-290, 1975.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Applied Elasticity** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Mechanics of Materials
3	**Course content**	Equilibrium Equations, Relations in Curvilinear Cylindrical and Spherical Coordinates Deformation: Displacements and Strains (6 hrs) Small Deformation Theory, Strain Transformation, Principal Strains, Spherical and Deviatoric Strains, Strain Compatibility, Curvilinear coordinate system: Cylindrical. Spherical system relations Material Behavior: (3 hrs) Linear Elastic Materials—Hooke's Law Physical Meaning of Elastic Moduli, Thermoelastic Constitutive Relations, Anisotropy - Basic Concepts, Material Symmetry. Restrictions on Elastic Moduli, Strain Energy Formulation and Solution Strategies:(2 hrs) Stress Formulation, Displacement Formulation, Principle of Superposition, Saint-Venant's Principle, Uniqueness theorem. Reciprocal theorem Two-Dimensional Formulation: (9 hrs) Plane Strain, Plane Stress, Generalized Plane Stress, Airy Stress Function, Polar Coordinate Formulation, Cartesian Coordinate Solutions; Curvilinear coordinates. Complex Variable Methods: Complex Formulation of the Plane Elasticity Problem, Resultant Boundary Conditions. General Structure of the Complex Potentials: Extension, Torsion, and Flexure of Elastic Cylinders (6 hrs) Extension Formulation; Torsion, Flexure Formulations, Flexure Problems without Twist Thermoelasticity (2 hrs) General Uncoupled Formulation, Two-Dimensional Formulation, Displacement Potential Solution. Stress Function Formulation 3D Elasticity: Displacement Potentials and Stress Functions (4 hrs) Helmholtz Displacement Vector Representation, Lame´'s Strain Potential, Galerkin Vector Representation, Papkovich-Neuber Representation; Spherical Coordinate Formulations, Stress Functions.

	Texts/References	**Texts:** **1.** MH. Sadd, Elasticity: Theory, Applications, and Numeric, 3rd Edition, Academic Press, 2014. 2. J. R. Barber, Elasticity, 3rd edition, Kluwer Academic, 2009. **References:** **2.** S. P. Timoshenko, J. N. Goodier, Theory of Elasticity, 3rd Edition, McGraw Hill Pub. 1970. **3.** Arthur P. Boresi, Ken Chong, James D. Lee, Elasticity in Engineering Mechanics, 2010, Wiley. **4.** Allan F. Bower, Applied Mechanics of Solids, 1st Edition, 2009, CRC Press. 4. R. W. Soutas-Little, Elasticity, DoverPublications, 1999 **5.** P Chou, N Pagano. Elasticity: Tensor, Dyadic and Engineering Approaches, DoverPub., 1992.
		6. A. S. Saada, "Elasticity Theory and Applications", Cengage Learning, New Delhi, 2014. **7.** Mark Kachanov, Igor Tsurkov, Handbook of Elasticity Solutions, Evener, 2003 **8.** W.S. Slaughter, The Linearized Theory of Elasticity, Birkhäuser, 2002 **9.** V. V. Novozhilov, Theory of Elasticity, Pergamon Press, 1961.

Mechanical Engineering

1	**Title of the course** (L-T-P-C)	**Kinematics and Dynamics of Machines (3-1-0-8)**
2	**Pre-requisite courses(s)**	Exposure to Engineering Mechanics (ME 201)
3	**Course content**	Introduction to Mechanisms. Position, velocity and acceleration analysis. Design of Cam Follower Mechanisms. Gear tooth profiles, spur gears and helical gears. Epicyclic Gear Trains. Dynamic Analysis of Mechanisms. Balancing. Analysis and Applications of Discrete and Continuous System Vibration.
4	**Texts/References**	**1.** B. Paul, Kinematics and Dynamics of Planar Mechanisms, Prentice Hall, 1979. **2.** J.J. Uicker, G.R. Pennock, and J.E. Shigley, Theory of Machines and Mechanisms (3rd edition), Oxford University Press, New York, 2005. **3.** S.S. Rattan, Theory of Machines (2nd edition), Tata McGraw Hill, New Delhi, 2005. **4.** R.L. Norton, Design of Machinery (3rd edition), Tata McGraw Hill, New Delhi, 2005. **5.** F.S. Tse, I.E. Morse, and R.T. Hinkle, Mechanical Vibrations, CBS Publishers, and Distributors, 1983. **6.** J.S. Rao, and K. Gupta, Introductory Course on Vibrations, Wiley Eastern, 1984. **7.** J.P. Den Hartog, Mechanical Vibrations, McGraw Hill, 1956.