M.TECH –ENGINEERING DESIGN

Department of Mechanical Engineering

This program is designed to enable an engineering graduate to develop specific capabilities in design, synthesis and analysis of a wide variety of mechanical engineering systems. The program focuses on developing design methodologies which involve high degree of research orientation supplemented with practical insights. Besides core courses (which are mandatory), a variety of electives are also offered to suit the taste of each individual student so that he/she can specialize in a particular area of Engineering Design. The students are periodically assessed by the teachers who are experts in chosen areas of Engineering Design, to ensure quality of education. On the whole, the Masters Program is committed to produce design engineers with excellent creative capabilities and calibre to solve real life problems curtailing to industry requirements, in tune with the objectives envisioned by the University.

CURRICULUM

First Semester				
Course Code	**Type**	**Course**	**L T P**	**Credits**
16MA611	FC	Mathematical Methods for Engineering Design	3 0 0	3
16ED600	FC	Continuum Mechanics	3 0 0	3
16ED601	FC	Selection of Materials and Processes	3 0 0	3
16ED650	SC	Applied Fluid Dynamics in Design	3 0 0	3
16ED651	SC	Mechanical Vibrations	3 0 0	3
16ED661	SC	Engineering Design Lab-I	0 0 1	1
16HU601	HU	Cultural Education*		P/F
*Non Credit course			**Credits**	**16**

Second Semester				
Course Code	**Type**	**Course**	**L T P**	**Credits**
16ED602	FC	Theory of Elasticity	4 0 0	4
16ED652	SC	Design of Thermal Systems	2 0 1	3
16ED653	SC	Finite Element Techniques	3 0 0	3
16ED654	SC	Optimization Techniques in Engineering	2 0 1	3
16ED662	SC	Engineering Design Lab-II	0 0 1	1
16ED663	SC	Engineering Design Lab-III	0 0 1	1
	E	Elective I	3 0 0	3
16EN600	HU	Technical Writing*		P/F
*Non Credit course			**Credits**	**18**

Third Semester				
Course Code	**Type**	**Course**	**L T P**	**Credits**
16ED655	SC	Fracture Mechanics	3 0 0	3
	E	Elective II	3 0 0	3
	E	Elective III	3 0 0	3
16ED664	SC	Engineering Design Lab-IV	0 0 1	1
16ED798	P	Dissertation		10
			Credits	**20**

Fourth Semester				
Course Code	**Type**	**Course**		**Credits**
16ED799	P	Dissertation		12
			Credits	**12**

Total Credits: 66

LIST OF COURSES

Foundation Core

Course Code	Course	L T P	Cr
16MA611	Mathematical Methods for Engineering Design	3 0 0	3
16ED600	Continuum Mechanics	3 0 0	3
16ED601	Selection of Materials and Processes	3 0 0	3
16ED602	Theory of Elasticity	4 0 0	4

Subject Core

Course Code	Course	L T P	Cr
16ED650	Applied Fluid Dynamics in Design	3 0 0	3
16ED651	Mechanical Vibrations	3 0 0	3
16ED652	Design of Thermal Systems	2 0 1	3
16ED653	Finite Element Techniques	3 0 0	3
16ED654	Optimization Techniques in Engineering	2 0 1	3
16ED655	Fracture Mechanics	3 0 0	3
16ED661	Engineering Design Lab-I	0 0 1	1
16ED662	Engineering Design Lab-II	0 0 1	1
16ED663	Engineering Design Lab-III	0 0 1	1
16ED664	Engineering Design Lab-IV	0 0 1	1

Electives

Course Code	Course	L T P	Cr
16ED700	Fundamentals of Analytical Dynamics	3 0 0	3
16ED701	Nonlinear Vibrations	3 0 0	3
16ED702	Modelling, Simulation and Analysis of Engineering Systems	3 0 0	3
16ED703	Advanced Mechanism Analysis and Design	3 0 0	3
16ED704	Theory of Plasticity	3 0 0	3
16ED705	Tribology	3 0 0	3
16ED706	Product Lifecycle Management	3 0 0	3
16ED707	Theory of Plates and Shells	3 0 0	3
16ED708	Computational Fluid Dynamics	3 0 0	3
16ED709	Design for Manufacture and Assembly	3 0 0	3
16ED710	Mechanics of Composite Materials	3 0 0	3
16ED711	Random Vibrations	3 0 0	3
16ED712	Computer Aided Product Development	3 0 0	3
16ED713	Micro-Electro-Mechanical Systems	3 0 0	3
16ED714	Machine Condition Monitoring	3 0 0	3
16ED715	Design of Experiments	3 0 0	3
16ED716	Computational Welding Mechanics	2 0 1	3
16ED717	Combustion Engineering	3 0 0	3

16ED718	Failure Analysis	3 0 0	3
16ED719	Reliability Engineering	3 0 0	3
16ED720	Design of IC Engines	3 0 0	3
16ED721	Multi-body Dynamics	3 0 0	3
16ED722	Bio-Mechanics	3 0 0	3
16ED723	Piping and Pressure Vessel Design	3 0 0	3
16ED724	Non-Linear Finite Element Method	3 0 0	3
16ED725	Introduction to Nonlinear Dynamics and Chaos	3 0 0	3

Project Work

Course Code	Course	Cr
16ED798	Dissertation	10
16ED799	Dissertation	12

16MA611 MATHEMATICAL METHODS FOR ENGINEERING DESIGN 3-0-0-3

Linear Algebra – system of equations, eigenvalues and eigenvectors, LU, QR decomposition and SVD. Ordinary differential equations – initial value problems (IVPs) and boundary value problems (BVPs), numerical methods and its implementation, stiffness. Partial differential equations – elliptic, parabolic and hyperbolic equations - solution techniques. Fourier series. Transform techniques – Fourier, Laplace and Wavelet transforms, FFT. Interpolation and Approximations – Linear, Lagrange and Spline interpolation, Least Square approximations. Random numbers and simulation. Introduction to calculus of variations.

TEXT BOOKS/ REFERENCES:

1. Strang G, "*Linear Algebra and its Applications*", Fourth Edition, Cengage learning, 2006.
2. William E. Boyce and DiPrima R. C., "*Elementary Differential Equations and Boundary Value Problems*", Ninth Edition, Wiley, 2008.
3.MichaelT.Heath, "*Scientific Computing an Introductory Survey*", Second Edition, Tata Mc Graw Hill Edition, 2002.
4. Erwin Kreyszig, "*Advanced Engineering Mathematics*", Ninth Edition, John Wiley & Sons, 2013.
5. Richard Courant and David Hilbert "*Methods of Mathematical Physics*", Volume 1, Wiley and Sons, 1989.

16ED600 CONTINUUM MECHANICS 3-0-0-3

Introduction to Continuum Mechanics: Vectors and tensors, Stress Principles, Kinematics of Deformation and Motion, Fundamental Laws and Equations.
Continuum models in Solid Mechanics: Linear Elasticity: Elasto-Statistics and Elasto-Dynamics; Nonlinear Elasticity: Elasto-Plasticity, Visco-elasticity, Hypo- and Hyper-Elasticity.
Continuum models in Heat Transfer: Conduction and Radiation, Nonlinear models, Transport phenomena problems: Momentum, Energy, and Mass transport.

TEXT BOOKS/ REFERENCES:

1. Gerhard A. Holzapfel, "*Non-linear Solid Mechanics- A Continuum Approach for Engineering*", Wiley, 2000.
2. Morton E. Gurtin, Eliot Fried, and Lallit Anand, "*The Mechanics and Thermodynamics of Continua*", Cambridge, 2009.
3. Martin H. Saad, "*Elasticity: Theory, Application and Numerics*", Second Edition, Butterworth Heinemann, 2000.
4. Michael Lai W., David Rubin, and Erhard Krempl, "*Introduction to Tensor Calculus and Continuum Mechanics*", Fourth Edition, Butterworth Heinemann, 2010.
5. Roger Temam and Alian Miranville, "*Mathematical Modeling in Continuum Mechanics*", Cambridge University Press, 2005.

16ED601 SELECTION OF MATERIALS AND PROCESSES 3-0-0-3

Overview of materials properties - mechanical, thermal, oxidation, corrosion and wear. Classification of materials - metals, ceramics, glasses, polymers, elastomers, composites, foams. Basics of materials selection. Selection procedure- translation, screening, ranking, supporting information. Multiple constraints and objectives. Design and selection of hybrid materials. Principles of process selection and classification of processes - casting, forging, molding, fabrication, welding, joining, machining, powder metallurgy, composite processing. Illustration of the principles of material/process selection with case studies-fly wheel, heat exchanger, spring, pressure vessel, kiln wall, passive solar heating, connecting rod, gear, gas turbine blade and vane, car wheels, and brake rotor. Rapid Prototyping, 3D Printing. Introduction to Surface Engineering.

TEXT BOOKS/REFERENCES:

1. Michael F. Ashby, "*Materials Selection in Mechanical Design*", Third Edition, Elsevier, 2005.
2. Michael F. Ashby, Shercliff H. R., and Cebon D., "*Materials: Engineering, Science, Processing and Design*", Elsevier Butterworth Heinemann, 2007.
3. Michael F. Ashby and Johnson K. W., "*Materials and Design: The Art and Science of Material Selection in Product Design*", Butterworth Heinemann, Oxford, UK, 2002.
4. ASM Handbook, Vol. 20, "*Materials Selection and Design*", ASM International, 1996.

16ED602 THEORY OF ELASTICITY 4-0-0-4

Fundamentals- Stress at a point-stress tensor - Analysis of stress and strain – Governing equations. Energy methods – Hooke's law & principle of superposition – Elastic strain energy - reciprocal relation – Maxwell Betti–Rayleiph Reciprocal theorem – First theorem of Castigliano – Expression for strain energy – Theorem of virtual work – Kirchhoff's theorem – second theorem of Castigliano – Engessers theorem Theories of failure – Mohr's theory of failure - stress space – Yield surfaces of Tresca and Von Mises. formulation of the general elasticity problem-Boundary Value Problems, Boussinesq problem-Three-dimensional problems, torsion and bending of non - circular prismatic bars-Membrane analogy. Straight beams and Asymmetrical bending- Euler – Bernoulli Hypothesis - Centre of flexure- shear stresses in thin walled open section – bending of curved beam – Thick walled cylinder subjected to internal & external pressures – stresses in composite tubes – sphere with purely radial displacements – stresses due to gravitation-rotating disks of uniform thickness – Disks of variable thickness – rotating shafts and cylinder. Thin-walled cylinders.

TEXT BOOKS/REFERENCES:

1. Timoshenko S. P. and Goodier J. N., "*Theory of Elasticity*", Third Edition, McGraw Hill, 1970.
2. Sokolnikoff I. S., "*Mathematical Theory of Elasticity*", Second Edition, McGraw Hill, 1956.
3. Den Hartog J. P., "*Advanced Strength of Materials*", Dover Publications, 1987.
4. Fung F. C., "*Foundations of Solid Mechanics*", Prentice Hall International, 1977.

5. Martin H. Saad, "*Elasticity: Theory, Application and Numerics*", Second Edition, Butterworth Heinemann, 2000.

16ED650 APPLIED FLUID DYNAMICS IN DESIGN 3-0-0-3

Lagrangian and Eulerian description, Reynolds transport theorem. Navier-Stokes equation, exact solutions - Poiseuille flow, Hagen Poisuille flow, flow between rotating cylinders. Laminar boundary layers, Von Karman Momentum integral equations, boundary layer separation. Introduction to turbulence, Onset of turbulence, laminar-turbulent transition, introduction to stability theory, Orr-Somerfield equation, mechanisms of laminar – turbulent transition, Kolmogorov length scale, mean motions and fluctuations, Reynolds equations, turbulent shear stress and closure problem, Prandtl's mixing length, Turbulence models. Pipe flows, laminar and turbulent flow through pipes. Self-excited vibration, fluid loading and response of body oscillators, flutter in aero foils.

TEXT BOOKS/REFERENCES:

1. Kundu P. K. and Cohen I. M., "*Fluid Mechanics*", Second Edition, Academic Press, 2002.
2. Munson B. R., Young D. F., Okiishi T., and Huebsch W. W., "*Fundamentals of Fluid Mechanics*". Sixth Edition, Wiley India, 2010.
3. White F. M., "*Fluid Mechanics*", McGraw Hill, 2010.
4. Schlichting H. and Gersten K., "*Boundary Layer Theory*", Eighth Edition, Springer, 2000.
5. Panton R. L., "*Incompressible Flow*", Second Edition, John Wiley & Sons, 2005.
6. Davidson P. A., "*Turbulence*", Oxford University Press, 2004.

16ED651 MECHANICAL VIBRATIONS 3-0-0-3

Overview of vibration of single degree of freedom (sdof) systems. Free and forced vibrations, rotating unbalance, support motion, whirling of shafts, vibration isolation, and vibration measuring instruments. Types of damping and damping materials- Response of sdof systems to arbitrary excitation-convolution integral, method of Fourier transforms. Two dof systems – undamped free vibration – formulation and solution of matrix eigenvalue problem for natural frequencies and mode shapes. Elastic and inertial coupling, orthogonality of modes, natural coordinates - Response of two dof systems to harmonic excitation - damped and undamped vibration absorbers. Multi dof systems – formulation and solution of matrix eigenvalue problem -orthogonality of modal vectors - expansion theorem – decoupling of equations of motion - modal analysis. Vibration of continuous systems – transverse vibration of a string, axial vibration of a rod, torsional vibration of a shaft, bending vibration of beam – natural frequencies and mode shapes – orthogonality properties of the eigen functions. Lagrange's equation.

TEXT BOOKS/REFERENCES:

1. Leonard Meirovitch, "*Principles & Techniques of Vibration*", Prentice Hall, 1996.
2. Thomson T., "*Theory of Vibration with Applications*", Fifth Edition, Pearson Education, 2003.
3. Leonard Meirovitch, "*Analytical Methods in Vibrations*", MacMillan, 1967.
4. Rao S. S., "*Mechanical Vibrations*", Fifth Edition, Prentice Hall, 2010.
5. Graham S. Kelly, "*Mechanical Vibrations*", Second Edition, McGraw Hill, 2000.

16ED652 DESIGN OF THERMAL SYSTEMS 2-0-1-3

Review of Heat Transfer, Applied thermodynamics and fluid machinery concepts
Design of Heat Exchangers. Types of heat exchangers-Standard Representation-classification. LMTD and -NTU method. Detailed design calculations for shell and tube heat exchangers, compact heat exchangers and plate heat exchangers.
Modelling of thermal equipment. Types of Models. Steady state simulation. Solution by successive substitution. Information Flow diagram. Typical case studies of piping systems and thermal system. Dynamic response of thermal systems.
Laboratory Component: Comprehensive case studies of some thermal/fluid systems using programming or numerical computing software. Usage of simulators for modeling of hydraulic systems.

TEXT BOOKS/REFERENCES:

1. Stoecker W. F., "*Design of Thermal Systems*". Third Edition Tata McGraw-Hill 2011.
2. Suryanarayana N. V. and Öner Arıcı, "*Design and Simulation of Thermal Systems*", McGraw-Hill, 2003.
3. Balaji C., "*Essentials of Thermal System Design and Optimization*". Ane Books, New Delhi, 2014.
4. Jaluria Y., "*Design and Optimization of Thermal Systems*", CRC Press, 2008.
5. Penoncello G. Steven, "*Thermal Energy Systems: Design and Analysis*", CRC Press 2015.

16ED653 FINITE ELEMENT TECHNIQUES 3-0-0-3

Fundamentals of governing equations in Solid Mechanics and Heat Transfer. Basic finite element procedures: Stiffness and Flexibility Approach, Direct Stiffness Method, Principle of Minimum Potential Energy, Strong form, Weak form, Variational formulation, Weighted Residual Method - Galerkin formulation, Formulation of the finite element equations - Element types - Basic and higher order elements –1D, 2D, 3D coordinate systems. Finite elements in Solid Mechanics: Analysis of trusses, beams and frames, Plane stress, Plane strain and Axisymmetric elements, Plate and shell elements. Isoparametric formulation. Finite elements in Heat Transfer: Formulations and solution procedures in 1D and 2D problems. Structural Dynamics: Formulation - Element mass matrices - Evaluation of Eigen values and Eigen vectors - Natural frequencies and mode shapes - Numerical time integration. Computer implementation of the Finite element method: Pre-processing, Element calculation, Equation assembly – Assembly Flowchart, ID, IEN, LM arrays, Solving – Numerical Integration – Gaussian Quadrature, Post processing – Primary and Secondary variables.

TEXT BOOKS/REFERENCES:

1. Thomas J. R. Hughes, "*The Finite Element Method – Linear Static and Dynamic Finite Element Analysis*", Dover Publications Inc, 2000.
2. Rao S. S., "*The Finite Element Method in Engineering*", Fourth Edition, Elsevier, 2007.
3. Daryl L. Logan, "*A First Course in the Finite Element Method*", Fourth Edition, Cengage Learning, 2007.
4. David V. Hutton, "*Fundamentals of Finite Element Analysis*", McGraw Hill, 2005.
5. Reddy J. N., "*An Introduction to the Mathematical Theory of Finite Elements*", Dover Publications, 2011.
6. Zienkiewicz O. C., "*The Finite Element Method for Solid and Structural Mechanics*", Sixth Edition, Butterworth-Heinemann, 2005.
7. Jacob Fish and Ted Belytschko, "*A First Course in Finite Elements*", Wiley Inter Science, 2007.

16ED654 OPTIMIZATION TECHNIQUES IN ENGINEERING 2-0-1-3

Introduction to optimization: Engineering applications, statement of an optimization problem, classification, global and local optima, single variable and multi variable optimization. Unconstrained optimization: One dimensional optimization, elimination and interpolation methods, direct search methods, steepest descent, conjugate gradient and Newton's method and their modifications. Lagrange multipliers and duality: Lagrange multipliers, Kuhn Tucker conditions, sufficiency for convex problems, Lagrangian duality, saddle point conditions. Constrained optimization: Method of feasible direction, gradient projection method, penalty function methods, augmented Lagrange multiplier method and constrained steepest descent. Modern methods of optimization: Genetic algorithms, simulated annealing, ant colony optimization, particle swarm methods, neural network based optimization, fuzzy optimization techniques. Multi objective optimization: Classical methods, Pareto optimality, modern methods for multi objective problems.
Lab practice: Developing codes to solve optimization problems using numerical computing software, use of optimization toolbox.

TEXT BOOKS/REFERENCES:

1. Rao S. S., "*Engineering Optimisation - Theory and Practice*", Fourth Edition, New Age International, 2009.
2. Chong E. K. P. and Zak S. H., "*An Introduction to Optimization*", John Wiley & Sons, N.Y.
3. Kalyanmoy Deb, "*Optimisation for Engineering Design*", Prentice Hall, 2000.
4. Achille Messac, "*Optmisation in Practice with MATLAB*", Cambridge University Press, 2015.

5. Mokhtar S. Bazaraa, "*Nonlinear Programming - Theory and Algorithms*", Wiley Intersceince, 2006.

16ED655 FRACTURE MECHANICS 3-0-0-3

Introduction and review of solid mechanics, plane elasticity- In-plane and out-of-plane problems-Airy's stress function-plate with a circular hole, elliptic hole. Fatigue-Failure of uncracked solids, stress-life approach, strain-life approach, Effect of mean stress, Miner's rule, Damage rule for irregular loads. Linear Elastic Fracture mechanics: Energetics of fracture, Griffith's energy balance, strain energy release rate, stability of crack growth-R curve, Eigen expansion for wedges and notches, stress ,displacement field at the crack tip for Mode I and Mode II, Stress Intensity Factor (SIF), Mode III fields, Westergaards function, Relationship between K and G, direction of crack propagation, mixed mode fracture, SIF for various geometries, Crack-Tip plasticity, Correction factor for plasticity effects, Experimental determination of K_c. Elastic-Plastic Fracture mechanics: J- contour integral, Relation between J-integral and CTOD, crack growth resistance curves, constraint effect in fracture, Experimental measurement of J integral. Fatigue - Growth of an initial crack, Fatigue crack growth analysis, Paris law, fatigue life, variable amplitude loading. Fracture mechanics in metals: Ductile fracture, cleavage fracture, ductile-brittle transition.

TEXT BOOKS/REFERENCES:

1. Anderson T. L., "*Fracture Mechanics: Fundamentals and Applications*", Second Edition, CRC Press, 1995.
2. Suresh S., "*Fatigue of Materials*", Second Edition, Cambridge University Press, 1998.
3. Barsom J. M. and Roffe S. T., "*Fracture and Fatigue Control in Structures*", Second Edition, Englewoods Cliffs, Prentice Hall, 1987.
4. Broek D., "*Elementary Engineering Fracture Mechanics*", Fourth Edition, Martinus Nijhoff, 1987.
5. Knott J. K., "*Fundamentals of Fracture Mechanics*", Third Edition, Butterworth Heinemann, 1993.

16ED661 ENGINEERING DESIGN LAB-I 0-0-1-1

Solid Modeling, GD & T, and Computational Methods Lab
CAD**:** Exercises covering sketching, modeling, assembly, interference checking, drafting, generation of BOM, GD&T.
Experimental Engineering Lab
Design of Experiments:
Introduction to Design of Experiments, Factorial Design, Response Surface Methods.

16ED662 ENGINEERING DESIGN LAB-II 0-0-1-1

Computer Aided Engineering Lab

Finite Element Analysis:
Exercises covering structural analysis, dynamic analysis, and thermo-mechanical coupled analysis using FEA packages, Finite element modeling of metal forming and metal cutting operations.
Computational Fluid Dynamics:
Exercises covering computational fluid dynamic analysis of steady, unsteady, and turbulent flows.

16ED663 ENGINEERING DESIGN LAB-III 0-0-1-1

Practical Stress Analysis:
Verification of stresses under mechanical loading using strain gauges, Calibration of torsional load cell, Modal testing and extraction of modal parameters.
Six-Sigma and Reliability Engineering Lab
Reliability testing, Implementation of Six Sigma concepts.
Mechanism Modeling and Analysis Lab:
Design and synthesis of simple mechanisms using synthesis tools, Force analysis of simple mechanisms.

16ED664 ENGINEERING DESIGN LAB-IV 0-0-1-1

Machine Condition Monitoring:
Machine condition monitoring studies using FFT analyzer and virtual instrumentation tools.
Advanced Vibrations Testing Lab
Experimental modal analysis for determination of natural frequency, logarithmic decrement & damping factor, damping ratio, and mode phase; Rotor Dynamics; Simulation of mode shapes using software packages.

16EN600 TECHNICAL WRITING P/F
(Non-credit Course)

Technical terms – Definitions – extended definitions – grammar checks – error detection – punctuation – spelling and number rules – tone and style – pre-writing techniques – Online and offline library resources – citing references – plagiarism – Graphical representation – documentation styles – instruction manuals – information brochures – research papers – proposals – reports (dissertation, project reports etc.)

TEXTBOOKS/REFERENCES:

1. H.L. Hirsch, *Essential Communication Strategies for Scientists, Engineers and Technology Professionals*, Second Edition, New York: IEEE press, 2002.
2. P.V. Anderson, *Technical Communication: A Reader-Centered Approach*, Sixth Edition, Cengage Learning India Pvt. Ltd., New Delhi, 2008, (Reprint 2010).

3. W.Jr. Strunk and E.B.White, *The Elements of Style*, New York. Alliyan & Bacon, 1999.

16ED700 FUNDAMENTALS OF ANALYTICAL DYNAMICS 3-0-0-3

Newtonian mechanics – Newton's laws, impulse, momentum, moment of a force, angular momentum, work and energy. Systems of particles, two-body central force problem. Analytical mechanics – Generalised coordinates, constraints, fundamentals of variational calculus, principle of virtual work, D'Alembert's principle, Hamilton's principle, Lagrange's equations of motion. Motion relative to rotating reference frames – Transformation of coordinates, rotating coordinate systems, motion relative to moving frames. Rigid body dynamics – Rigid body kinematics, linear and angular momentum, translation theorem for angular momentum, kinetic energy of a rigid body, principal axes, equations of motion, Euler's angles. Hamiltonian mechanics – The principle of least action, the Legendre transformation, Hamilton's equations, Poisson's brackets, canonical transformations, Hamilton-Jacobi equations.

TEXT BOOKS/REFERENCES:

1. Leonard Meirovitch, "*Methods of Analytical Dynamics*", Dover Publications, New York, 1970.
2. Goldstein H., Poole C. P., and Safko J. L., "*Classical Mechanics*", Third Edition, Pearson Education, 2014.
3. Woodhouse N. M. J., "*Introduction to Analytical Dynamics*", Springer Verlag, London, 2009.
4. Francis C. Moon, "*Applied Dynamics*", John Wiley & Sons, New York, 1998.
5. Haim Baruh, "*Analytical Dynamics*", McGraw Hill International, 1999.

16ED701 NONLINEAR VIBRATIONS 3-0-0-3

Linear and nonlinear systems-conservative and non-conservative systems-potential well, phase planes, fixed points, periodic, quasi-periodic and chaotic responses; local and global stability- bifurcations. Equations of motion – linearization techniques, ordering techniques – Duffing, Van der Pol and Mathieu Hill equations. Analytical solutions – perturbation techniques - method of multiple scales, averaging method (KBM) – Harmonic balance method. Bifurcations of periodic solutions. Numerical techniques – time response, phase plots, FFT, Poincare' maps, strange attractors, Lyapunov exponents, basins of attraction, cell mapping techniques, Floquet theory. Examples – free and forced vibration of Duffing oscillator – primary, sub harmonic, super harmonic resonances, jump phenomenon, multiple solutions, and combination resonances. Van der Pol oscillator – limit cycle oscillation - entrainment – synchronization. Parametrically excited systems – Mathieu's equation. Discontinuous nonlinear systems - Stick-slip oscillator, Impact oscillator.

TEXT BOOKS/REFERENCES:

1. Nayfeh A. H. and Mook D. T., "*Nonlinear Oscillations*", Wiley-Interscience, 1979.
2. Hayashi C., "*Nonlinear Oscillations in Physical Systems*", McGraw-Hill, 1964.
3. Thomsen J. J., "*Vibrations and Stability, Advanced Theory, Analysis and Tools*", Springer, 1997.
4. Nayfeh A. H. and Balachandran B., "*Applied Nonlinear Dynamics*", Wiley, 1995.
5. Seydel R., "*From Equilibrium to Chaos: Practical Bifurcation and Stability Analysis*", Elsevier, 1988.

16ED702 MODELING, SIMULATION AND ANALYSIS OF ENGINEERING SYSTEMS 3-0-0-3

Introduction to linear systems, principle of super position-Modelling of engineering systems-mechanical, electrical, fluid, thermal and mixed discipline systems-Free, forced and transient response of first and second order systems-Solution of differential equation using Laplace Transforms-Time domain and Frequency domain analysis-State space representation-System characteristics from state space representation-Solving the state equations-Stability criterion through the state transition matrix-Control system design in state space-Linear optimal control.

TEXT BOOKS/REFERENCES:

1. Philip D. Cha, James J. Rosenberg, and Clive L. Dym, "*Fundamentals of Modelling and Analysis of Engineering Systems*", Cambridge University Press, 2000.
2. Woods Robert L. and Lawrence Kent L., "*Modelling and Simulation of Dynamic Systems*", Prentice Hall, 1997.
3. Ashish Tiwari, "*Modern Control Design with MATLAB and SIMULINK*", John Wiley, 2002.

16ED703 ADVANCED MECHANISM ANALYSIS AND DESIGN 3-0-0-3

Review of fundamentals of kinematics - Mobility Analysis - Formation of one D.O.F. multiloop kinematic chains, Network formula - Gross motion concepts- Position Analysis – Vector loop equations for four bar- slider crank- inverted slider crank- geared five bar and six bar linkages- Analytical methods for velocity and acceleration Analysis– four bar linkage, Types of complex mechanisms- velocity-acceleration analysis of complex mechanisms by the normal acceleration and auxiliary point methods-Goodman's indirect acceleration analysis- Fixed and moving centrodes- inflection points and inflection circle-Euler Savary equation, graphical constructions – cubic of stationary curvature- Type synthesis – Number synthesis – Associated Linkage Concept- Dimensional synthesis – function generation- path generation- motion generation- Graphical methods-Pole technique inversion technique-point position reduction-two- three and four position synthesis of four- bar mechanisms-Analytical methods- Freudenstein's Equation-Bloch's Synthesis- synthesis of coupler curve based mechanisms- Cognate Linkages-parallel motion Linkages - Kinematics of Robot - Introduction - Topology arrangements of robotics arms – Kinematic Analysis of Spatial RSSR mechanism - Direct Kinematic Model – Mechanical structure and notations, Description of links and joints, Kinematic modeling of manipulator, Denavit-Hartenberg notation, Kinematic relationship between adjacent links, Manipulator Transformation Matrix; Inverse Kinematic Model – Manipulator Workspace, Solvability, Solution techniques, Closed form solution - Study and use of mechanism using software packages.

TEXT BOOKS/REFERENCES:

1. Parviz Nikravesh, "*Computer Aided Analysis of Mechanical System*", Prentice Hall, 1986.
2. Sandor G. N. and Erdman A. G., "*Advanced Mechanism Design: Analysis and Synthesis*", Vol.2, Prentice Hall, 1984.
3. Chung-Ha Suh and Charles Radcliffe, "*Kinematics and Mechanism Design*", John Wiley & Sons, 1978.
4. Kenneth J. Waldron and Gary L. Kinzel, "*Kinematics, Dynamics and Design of Machinery*", John Wiley & Sons, 1999.
5. Rao V. Dukkipati, "*Spatial Mechanisms: Analysis and Synthesis*", CRC Press, 2001.
6. Mittal R. K. and Nagrath I. J., "*Robotics and Control*", First Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2003.
7. John J. Creig, "Introduction to Robotics, Mechanics and control", Pearson Education (Singapore) Pte. Ltd., 2002.
8. Mittal R. K. and Nagrath I. J., "*Robotics and Control*", First Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2003.
9. John J. Creig, "*Introduction to Robotics, Mechanics and control*", Pearson Education (Singapore) Pte. Ltd., 2002.

16ED704 THEORY OF PLASTICITY 3-0-0-3

Mathematics-Notation-Tensors-Vector and tensor calculus, curvilinear coordinates. Strain Analysis: Displacement, Deformation (strain Tensor), principal strains, Mohr circle of strains, compatibility, Plane strain, Displacement boundary conditions. Stress Analysis: Stress (Stress tensor), Mohr's circle of stress, Plane stress, Stress boundary conditions Constitutive Relations: First and Second Laws of TD, Elasticity, Inelasticity, Visco-plasticity, Rate-Independent plasticity, Yield criteria, Flow rules, Hardening rules, Advanced models, Bounding-surface plasticity.Constrained plastic flow: Hollow cylinders and hollow spheres subject to internal and external pressures, Cavity expansion, Torsion, Bending. Limit Analysis: Plastic dissipation, Drucker's postulate, Lower bound theorem, Upper Bound theorem, Applications, numerical Implementation.

TEXT BOOKS/REFERENCES:

1. Lubliner J., "*Plasticity Theory*", MacMillan, New York, 1990.
2. Dally J. W. and Riley W. F., "*Experimental Stress Analysis*", Third Edition, McGraw-Hill, 1991.
3. Fung Y. C., "*A First Course in Continuum Mechanics*", Second Edition, Prentice Hall, 1977.

4. Hill R., “*The Mathematical Theory of Plasticity*”, Clarendon Press, 1998.
5. Simo J. C. and Hughes T. J. R., “*Computational Inelasticity*”, Springer Verlag, 1998.

16ED705 TRIBOLOGY 3-0-0-3

Engineering Surfaces - surface topography-Analysis of surface roughness-Conformal and non-conformal surfaces-Greenwood and Williamson Model-Contact mechanics, Dry contacts-Friction, Modern theories of friction-Stick-Slip Phenomenon-Liquid-Mediated contacts-Wear, Effect of surface roughness, friction, and sliding speed on wear-Ferrography - Oil Analysis Program - Basic equations of Flow, Navier-Stokes equation, Generalized Reynolds’s equation-Hydrodynamic lubrication-Boundary lubrication-Bearing materials-Hydrodynamic real (finite) bearings-Design considerations in journal and thrust bearings-Hydrodynamic instability-Hydrodynamic and hydrostatic gas bearings-Idealized slider and journal bearings-Oil flow and Thermal analysis of bearings-Bearing selection and design-Dynamically loaded bearings-Squeeze film bearings.

TEXT BOOKS/REFERENCES:

1. Majumdar B. C., “*Tribology of Bearings*”, A. H. Wheeler and Company, 1986.
2. Bharat Bhushan, “*Introduction to Tribology*”, John Wiley & Sons, 2002.
3. Moore and Desmond. F., “*Principles and Applications of Tribology*”, Pergamom Press, 1975.
4. Dudley D. Fuller, “*Theory and Practice of Lubrication for Engineers*”, John Wiley & Sons, 1984.
5. Johnson K. L., “*Contact Mechanics*”, Cambridge University Press, 1987.

16ED706 PRODUCT LIFECYCLE MANAGEMENT 3-0-0-3

Introduction to Product life cycle - PLM-PDM concepts - present market constraints - need for collaboration – Object oriented programming concepts - internet and developments in server - client computing. Components of a typical PLM / PDM setup - hardware and software - document management - creation and viewing of parts and documents- version control -case studies. Configuration management: Base lines - product structure - configuration management – Effectivity - case studies. Creation of projects and roles - life cycle of a product- life cycle management - automating information flow-workflows - creation of work flow templates -life cycle - work flow integration - case studies. Change management: Change issue- change request- change investigation- change proposal - change activity - case studies. Generic products and variants: Data Management Systems for FEA data - Product configuration - comparison between sales configuration and product configuration -generic product modeling in configuration model - use of order generator for variant creation-registering of variants in product register-case studies. Implementation issues and best practices.

TEXT BOOKS/ REFERENCES:

1. Kevin Otto and Kristin Wood, “*Product Design*”, Pearson, 2001.

2. Daniel Amor, "*The E-Business Revolution*", Prentice Hall, 2000.
3. David Bed Worth, Mark Henderson, and Phillip Wolfe, "*Computer Integrated Design and Manufacturing*", McGraw Hill, 1991.
4. Terry Quatrain, "*Visual Modeling with Rational Rose and UML*", Addison Wesley, 1998.

16ED707 THEORY OF PLATES AND SHELLS 3-0-0-3

Introduction - Formulation of governing equations and associated boundary conditions by equilibrium and energy methods, Rectangular plates - Solution of equation by double and single series, Circular plates - symmetric and un-symmetric loading cases, Continuous Plates, Plates with various plan forms, Plates with variable flexural rigidity, Plates on elastic foundation. Numerical and approximate methods - finite difference method - finite element method, energy methods and other variational methods.Introduction, Theory of Surfaces - first and second fundamental forms - principal curvatures, Formulation of governing equations in general orthogonal curvilinear coordinates based on classical assumptions - various shell theories, Membrane theory - governing equations - shells of revolution - application to specific geometric shapes - axisymmetric and non-axisymmetric loading cases. General theory of shells - governing equations and associated boundary conditions for specific geometry of shells (cylindrical, conical and spherical shells) - classical solutions - finite difference and finite element methods applied to shell problems.

TEXT BOOKS/REFERENCES:

1. Vardhan T. K. and Bhaskar K., "*Analysis of Plates: Theory and Problems*", John Wiley & Sons, 1999.
2. Timoshenko S. and Woinowsky Krieger S., "*Theory of Plates and Shells*", McGraw-Hill, 1969.
3. Chandrashekhara K., "*Theory of Plates*", Universities Press, 2001.

16ED708 COMPUTATIONAL FLUID DYNAMICS 3-0-0-3

Introduction: Conservation equations – mass, momentum, and energy equations; convective forms of the equations and general description. Classification and overview of Numerical Methods: Classification into various types of equation; parabolic elliptic and hyperbolic; boundary and initial conditions; over view of numerical methods. Discretisation techniques using finite difference methods: Taylor-Series and control volume formulations. One dimensional steady state diffusion problems; discretization technique. Solution methodology for linear and non-linear problems: Point-by-point iteration, TDMA. Two and three dimensional discretization. Discretization of unsteady diffusion problems: Explicit, Implicit and Crank-Nicolson's algorithm; stability of solutions. One dimensional convection-diffusion problem: Central difference scheme. Discretization based on analytical approach (exponential scheme). Hybrid and power law discretization techniques. Higher order schemes (QUICK algorithm). Discretization of incompressible flow equations. Pressure based algorithm: SIMPLE, SIMPLER etc. Introduction to turbulence modeling: Reynolds averaged Navier-Stokes equations, RANS modeling, DNS and LES, CFD simulation of flow problems using commercial packages.

TEXT BOOKS/REFERENCES:

1. Patankar S. V., "*Numerical Heat Transfer and Fluid Flow*", Hemisphere Publishing Corporation, 1980.
2. Anderson D. A., Tannehill J. C., and Pletcher R. H., "*Computational Fluid Mechanics and Heat Transfe*r", Second Edition, Taylor & Francis, 1997.
3. Ferziger J. H. and Peric M., "*Computational Methods for Fluid Dynamics*", Third Edition, Springer, 2002.
4. Versteeg H. K. and Malalasekera W., "*An Introduction to Computational Fluid Dynamics: The Finite Volume Method*", Pearson Education, 2007.
5. Date A. W., "*Introduction to Computational Fluid Dynamics*", Cambridge University Press, 2005.

16ED709 DESIGN FOR MANUFACTURE AND ASSEMBLY 3-0-0-3

DFM approach, DFM guidelines, Standardization. Group technology, Value engineering, development and evaluation of alternative solutions, Poke – Yoke principles. Tolerance analysis – process capability, process capability metrics, cost aspects, geometric tolerances, cumulative effect of tolerances, Interchangeable and selective assembly. Control of axial play – secondary machining operations, laminated shims. Datum systems – grouped datum systems – geometric analysis and applications. True position theory – true position tolerancing, zero true position tolerance, functional gauges, paper layout gauging, compound assembly. Form design of castings and weldments – Redesign of castings – redesigning cast members using weldments. Tolerance charting technique, centrality analysis – computer aided tolerance charting. Design for machining. Design features to facilitate machining – functional and manufacturing datum features, redesign for manufacture.Environmental objectives – Global issues – Regional and local issues– Basic DFE methods – Design guide lines – Example application – Lifecycle assessment – Basic method – AT&T's environmentally responsible product assessment - Techniques to reduce environmental impact – Design to minimize material usage – Design for disassembly – Design for recyclability – Design for remanufacture – Design for energy efficiency – Design to regulations and standards.

TEXT BOOKS/ REFERENCES:

1. Boothroyd G., Dewhurst P., and Knight W., "*Product Design for Manufacture and Assembly*", Second Edition, Marcel Dekker, New York, 2002.
2. Harry Peck, "*Designing for Manufacture*", Pitman Publications, 1983.
3. Spotts M. F., "*Dimensioning and Tolerance for Quantity Production*", Prentice Hall, 1983.
4. Boothroyd G., "*Design for Assembly: The Road to Higher Productivity*", Assembly Engineering, 1982.

5. Creveling C. M., "*Tolerance Design - A Hand Book for Developing Optimal Specifications*", Prentice Hall, 1997.

16ED710 MECHANICS OF COMPOSITE MATERIALS 3-0-0-3

Composite materials and its characteristics-Analysis of an orthotropic lamina-Analysis of laminated composites-Fracture mechanics-Determination of strain energy release rate-Manufacturing Processes-Testing of Composites-Stress analysis - interlaminar stresses and free edge effects-Failure Criteria-Whitnessnuismer failure criteria-Vibration and stability analysis- Introduction to Design of Composite Structures –Introduction to Structural -Design and Analysis of mechanically fastened joints- Optimization Concepts –Fatigue in Composites-Effects of holes in Laminates –Transverse shear effects-Post curing shapes of Unsymmetric Laminates-Environmental Effects on Composite Materials-Study of Hygrothermic effects on laminates-Quality control and Characterisation of Composite-Non Destructive testing on Composites-Recycling of Composites –Primary and Secondary Recycling of Composites.

TEXT BOOKS/REFERENCES:

1. Mallick P. K., "*Fiber Reinforced Composite Materials - Manufacturing and Design*", Marcel Dekker, 1993.
2. Robert M. Jones, "*Mechanics of Composite Materials"*, Second Edition, Taylor and Francis, 1999.
3. Halpin J. C., "*Primer on Composite Materials Analysis*", Techomic, 1984.
4. Mallick P. K. and Newman S., "*Composite Materials Technology - Processes and Properties*", Hansen, 1990.
5. Agarwal B. D. and Broutmen L. J., "*Analysis and Performance of Fibre Composites*", John Wiley & Sons, 1990.

16ED711 RANDOM VIBRATIONS 3-0-0-3

Concept of probability - Theory of random variables - Probability structure of random variable - Stationary and non-stationary random process - Calculus of random process - Spectral decomposition of random process - Gaussian, Poisson and Markov process - Response of single degree of freedom, multi degree of freedom and continuous systems to random excitation - Failure modes in random vibration-level crossing statistics-First excursion failure-Rice formula - Fatigue failure - Palmgren – Miner cumulative damage law - Application to civil, mechanical and ocean structures - Introduction to non linear random vibration.

TEXT BOOKS/REFERENCES:

1. Nigam N. C. and Narayanan S., "*Applications of Random Vibrations*", Springer Verlag, 1994.
2. Lin Y. K. and Cai G. K., "*Probabilistic Structural Dynamics*", McGraw Hill, 1995.
3. Crandall S. H., "*Random Vibrations - Vol. I & II*", MIT Press, 1962.

4. Newland D. E., “*An Introduction to Random Vibrations and Spectral Analysis*”, Longman, 1984.

16ED712 COMPUTER AIDED PRODUCT DEVELOPMENT 3-0-0-3

Introduction to New Product design – Creativity and Innovation - concept design – parametric sketching – constraints- Feature based modelling - synchronous technology – contemporary software – Kernel and graphics engine – Hardware requirements - data exchange formats. Computers in Design –– Assembly modelling – creation of BOM – issues in large assemblies - associative features – Sheet metal components, nesting and development – plastic parts with draft and shrinkage allowance – Reverse engineering of components – tolerance analysis – check for interferences and mass property calculations. Computers applications in tool design – mould design – jigs and fixtures design – mechanism design and analysis – Rapid tooling – Computer aided inspection. Computers in Design Productivity – customisation using various software like visual basic, pro/program, script, LISP etc. to write applications like design of shafts, gears etc. Managing product design data – version control – library creation – catalogue making – standardization for design – collaborative design among peer groups – design optimization for geometry - Design check, approval and validation. – Introduction to design patenting rules.

TEXT BOOKS/ REFERENCES:

1. Robert G. Cooper and Scott J. Edgett, “*Product Innovation and Technology Strategy*”, Product Development Institute, 2009.
2. Fuh J. Y. H., “*Computer-Aided Injection Mold Design and Manufacture*”, Marcel Dekker, 2004.
3. Chua C. K., Leong K. F., and Lim C. S., “*Rapid Prototyping: Principles and Applications*”, Third Edition, World Scientific Publishing Co. Pvt. Ltd., 2010.
4. Rao P. N., “*CAD/CAM: Principles and Applications*”, Second Edition, Tata McGraw-Hill, 2004.

16ED713 MICRO-ELECTRO-MECHANICAL SYSTEMS 3-0-0-3

Introduction: An overview of micro-electro-mechanical devices and technologies, and an introduction to design and modelling. Standard microelectronic fabrication technologies; bulk micromachining, surface micromachining, bonding technologies, related fabrication methods, and creating process flows. Mechanical, thermal, electrical, magnetic, optical, and chemical properties of materials. Introduction to lumped modeling of systems and transducers; an overview of system dynamics. MEMS examples, energy methods, the thermal energy domain; modeling dissipative processes, Fluids and Transport.

TEXT BOOKS/REFERENCES:

1. Tai–Ran Hsu, “*MEMS& Microsystems Design, Manufacture and Nanoscale Engineering*”, Second Edition, John Wiley & Sons, 2008.

2. Mohamed Gad-el-Hak, "*MEMS: Design and Fabrication (Mechanical Engineering)*", CRC; First Edition, 2005.
3. Marc J. Madou, "*Fundamentals of Microfabrication, the Science of Miniaturization*", Second Edition, CRC, Press, 2002.
4. Sami Franssila, "*Introduction to Microfabrication*", John Wiley; First Edition, 2004.
5. John A. Pelesko and David H. Bernstein, "*Modeling MEMS and NEMS*", First Edition, CRC; 2002.

16ED714 MACHINE CONDITION MONITORING 3-0-0-3

Introduction and Background: Condition Monitoring Methods, Vibration Measurement and Analysis, Benefits of Vibration Analysis, Vibration Transducers, Vibration Signals from Rotating and Reciprocating Machines, Infrared Thermography, Oil Analysis and Tribology, Ultrasonics, Motor Current Analysis. Signals and systems: Introduction to signal processing, sampling and aliasing, Nyquist sampling theorem, analog to digital conversion, Fourier transform and Fourier series, discrete Fourier transform, properties, fast Fourier transform, Filtering: FIR and IIR filters Implementation. Overview of wavelet transform: Continuous wavelet transform, discrete wavelet transform, wavelet packets, Applications in denoising and feature extraction. Condition monitoring of gearboxes, Condition Monitoring of ball/roller bearings, Condition monitoring in IC Engines, Condition monitoring in electrical machines, Monitoring and Control of Machining, Precision Manufacturing Process Monitoring with Acoustic Emission, Tool Condition Monitoring, Fault-Trending and Prognostics: Trend Analysis, Advanced Prognostics, Data-Driven Models and Hybrid Models.

TEXT BOOKS/REFERENCES:

1. Robert Bond Randall, "*Vibration-Based Condition Monitoring: Industrial, Aerospace and Automotive Applications*", John Wiley & Sons, 2011.
2. George Vachtsevanos, Frank L. Lewis, Michael Roemer, Andrew Hessand Biqing Wu., "*Intelligent Fault Diagnosis and Prognosis for Engineering Systems*", Wiley, 2006.
3. John G. Proakis and Dimitris G. Manolakis, "*Digital Signal Processing Principles, Algorithms, Applications*", Fifth Edition, PHI, 2003.
4. Stephane Mallat, "*A Wavelet Tour of Signal Processing: The Sparse Way*", Third Edition, Academic Press, 2009.
5. Kihong Shin and Joseph K. Hammond, "*Fundamentals of Signal Processing for Sound and Vibration Engineers*", John Wiley & Sons Ltd., 2008.

16ED715 DESIGN OF EXPERIMENTS 3-0-0-3

Introduction to Research, Review of linear estimation, basic designs and Design Principles, Completely Randomized Designs, Treatment Comparisons, Diagnostics and Remedial Measures, Experiments to Study Variances, Random Effects Models. Factorial Designs: General factorial experiments, factorial effects; best estimates and testing the significance of factorial effects; study of 2n and 3r factorial experiments in randomized blocks; complete and partial confounding, construction of symmetrical confounded factorial experiments, fractional replications for symmetrical factorials, split plot and strip-plot experiments. Complete Block Designs: Balanced incomplete block designs, simple lattice designs, Two-associate partially balanced incomplete block designs: association scheme and intra block analysis, group divisible design. Analysis of Covariance including a Measured Covariate Split-Plot Designs, Repeated Measures Designs, missing plot technique:- General theory and applications, Analysis of Co-variance for CRD and RBD. Application areas: Response surface experiments; first order designs, and orthogonal designs; clinical trials, treatment-control designs; model variation and use of transformation; Tukey's test for additivity.

TEXT BOOKS/ REFERENCES:

1. Douglas C. Montgomery, "*Design and Analysis of Experiments*", Seventh Edition, Wiley, 2010.
2. Jiju Antony, "*Design of Experiments for Engineers and Scientists*", Elsevier, 2003.
3. Larry B. Barrentine, "*An Introduction to Design of Experiments: A Simplified Approach*", ASQ Quality Press, 1999.
4. Paul G. Mathews, "*Design of Experiments with MINITAB*", ASQ Quality Press, 2003.
5. Mark J. Anderson and Patrick J. Whitcomb, "*DOE Simplified: Practical Tools for Effective Experimentation*", Second Edition, Productivity Press, 2007.

16ED716 COMPUTATIONAL WELDING MECHANICS 2-0-1-3

Computer Simulation of Welding Processes - The Computing Environment, Computational Geometry, Models for Welding Heat Sources-Theoretical Formulations-Model Considerations-Gaussian Surface Flux Distribution-Hemi-spherical Power Density Distribution-Ellipsoidal Power Density Distribution-Double Ellipsoidal Power Density Distribution, Kinematic Models for Welding Heat Transfer, Evaluation of the Double Ellipsoid Model, Modeling Thermal Stresses and Distortions in Welds, Microstructure Modeling in Heat Affected Zone (HAZ), Spatial Integration Schemes. Thermal Analysis of Welds -Heat Transfer Theory, Weld Heat Source, Data to characterize a Weld Heat Source, Modeling a Weld Heat Source, Heat Transfer in Welds. Evolution of Microstructure Depending on Temperature - Microstructure Model, Data Structures, Steady State Temperature Field, Clipped transient temperature field, Hardness Calculation of the HAZ. Evolution of Microstructure Depending on Deformations - Properties for Modeling, Stresses, Strains and Deformations, Rate Independent Isotropic Plasticity, Linear Viscous Isotropic Plasticity around melting point, Rate dependent isotropic plasticity, Changing Constitutive Equations in Time and Space.

TEXT BOOKS/ REFERENCES:

1. John A. Goldak and Mehdi Akhlagh, "*Computational Welding Mechanics*", Springer US, 2005.

2. Lars-Erik Lindgren, "*Computational Welding Mechanics*", Woodhead Publishing in Materials, 2007.
3. Grong O., "*Metallurgical Modelling of Welding*", Second Edition, The Institute of Materials, 1997.
4. Kou S., "*Welding Metallurgy*", Second Edition, John Wiley Publications, New York, 2003.
5. Metals Handbook, Vol. 6, "*Welding, Brazing and Soldering*", ASM International, Metals Park, Ohio, 1988.

16ED717 COMBUSTION ENGINEERING 3-0-0-3

Introduction - importance of combustion. Chemical thermodynamics and chemical kinetics. Important chemical mechanisms. Coupling chemical and thermal analysis of reacting systems.
Premixed systems: detonation and deflagration, laminar flames, burning velocity, flammability limits, quenching and ignition. Turbulent premixed flames.
Non-premixed systems: laminar diffusion flame jet, droplet burning. Practical aspects of coal combustion, Numerical aspects of combustion.

TEXT BOOKS/REFERENCES:

1. Stephen R. Turns, "*An Introduction to Combustion: Concepts and Applications*", McGraw-Hill Education, 2011.
2. Kenneth K. Kuo, "*Principles of Combustion*", John Wiley & Sons, 2005.
3. Thierry Poinsot and Denis Veynante, "*Theoretical and Numerical Combustion*", Edwards, R. T. Inc, 2005.
4. Irvin Glassman, Rechard A. Yetter, and Nick G. Glumac, "*Combustion*", Academic Press, 2008.

16ED718 FAILURE ANALYSIS 3-0-0-3

Introduction, causes of failures, classification, steps in failure analysis, tools, sample selection and treatment, materials analysis, equipments, Metallography, commonly used NDT methods. Failure mechanisms, overload failure, ductile and brittle fracture, ductile to brittle transition, stress concentration approach. Fracture mechanics approach, Fatigue mechanisms, classical fatigue prevention and prediction, fractography, damage tolerant fatigue approach. Wear failures, adhesive, abrasive, erosive, corrosive wear. Elevated temperature failures, creep, creep crack branching, thermal fatigue, microstructural instability and oxidation. Corrosion failures, types and their identification, failures of cast and welded components, failure in cold worked and heat treated components. Case studies.

TEXT BOOKS/REFERENCES:

1. Jones D. R. H., "*Engineering Materials 3 – Materials Failure Analysis: Case Studies and Design Implications*", Pergamon Press, 1993.

2. ASM Handbook, Vol. 11, "*Failure Analysis and Prevention*" Edited by, ASM Publications, 2002.
3. Colangelo Vito J. and Heiser F., "*Analysis of Metallurgical Failures*", Second Edition, John Wiley & Sons, Inc., 1987.
4. Briant C. L., "*Metallurgical Aspects of Environmental Failures*", Elsevier Science Publishers, 1985.
5. McCall J. L. and French P. M. (ed), "*Metallography in Failure Analysis*", Springer Science & Business Media, 2012.

16ED719 RELIABILITY ENGINEERING 3-0-0-3

Concept and definition of reliability-reliability mathematics-failure distributions, hazard rate function; bathtub curve, hazard models-exponential, Rayleigh, Weibull, Normal, Lognormal distributions-MTTF, MTBF, median time to failures-failure models-Reliability of systems- serial and parallel configurations-mixedconfiguration-K-out-of-n-systems-redundancy-types-stand by systems-Reliability of complex configurations-event-space method-path tracing and decomposition methods-use of tie sets and cut sets-three-state devices-Markov analysis-Design for reliability-Reliability allocation-derating-maintainability-Design for maintainability-Availability, maintenance and spare provisioning-failure data analysis-reliability testing-types-test time calculations-burn-in, acceptance testing for reliability-identifying failure distribution.

TEXT BOOKS/ REFERENCES:

1. Charles Ebeling, "*An Introduction to Reliability and Maintainability Engineering*", Tata McGraw Hill, 2000.
2. Richard E. Barlow, Frank Proschan, "*Mathematical Theory of Reliability*", SIAM, 1996.
3. Massimo Lazzaroni, "*Reliability Engineering: Basic Concepts and Application in ICT*", Springer, 2011.
4. Alessandro Birohini, "*Reliability Engineering – Theory and Practice*", Sixth Edition, Springer, 2010.
5. Srinath L. S., "*Reliability Engineering*", Fourth Edition, East West Publishers, 2005.

16ED720 DESIGN OF IC ENGINES 3-0-0-3

Scope for developments in IC Engine Design – Energy consumption & Power requirements of a vehicle – Geometric & Kinematic models for an IC engine – Kinematic analysis for a Conventional IC engine – Selection of geometric ratios for IC engines – Selection of rod ratio for IC engines – Effect of Piston Dwell on engine performance.
Development of Thermodynamic Models for Engine Design – Conceptual & Thermodynamic description for expansion in IC engines – Strategies for complete expansion in IC engines – Work distribution analysis of IC Engine Cycles – Mechanical losses in an engine – Estimation of Engine Frictional Power – Method to control frictional power in engines – Design & selection of systems for best Heat Release –

Stochiometry of real combustion – Thermo-chemistry of Engine Combustion – Fuel Induction Systems for SI Engines – Design of Port Injection Systems for SI Engines – Fuel evaporation in ports of SI engines – Means & Methods of Homogeneous Charge Combustion.
Design of Engine Cylinder for creation of a selected turbulent flow – Design of intake systems for better in-cylinder turbulent flow – The chemistry of fuel combustion in SI engines – Strategies to achieve a fast cycle with high & safe peak pressure in SI Engines – Analysis & Control of Knock in SI engines – Design & Analysis of Combustion System for Diesel engines – Models for Design & Selection of Injection System – Auto Ignition, Premixed & Diffusive Combustion in CI engines – Engine Heat Transfer – Design of ideal intake systems for IC engines – Maximization of flow through intake & exhaust systems – Design steps for intake & exhaust systems – IC Engine Design Strategies Vs Exhaust Emissions.

TEXT BOOKS/REFERENCES:

1. Ramos J. I., "*Internal Combustion Engine Modeling*", CRC Press, 1989.
2. Charles Fayette Taylor, "*The Internal Combustion Engine in Theory & Practice: Vol. 1 & 2*", The MIT Press, 1985.

16ED721 MULTI BODY DYNAMICS 3-0-0-3

Introduction - Motion and constraints – degrees of freedom – kinematic and dynamic analysis – dynamical equations in different forms – planar and spatial dynamics. Kinematics of rigid bodies – velocity and acceleration equations – constrained kinematics- formulation of driving and joint constraints – computational methods in kinematics. Forms of dynamic equations – D'Alembert's principle – Newton Euler equations – constrained dynamics – augmented formulation – embedding techniques – amalgamated formulation. Virtual work and Lagrangian dynamics – constrained dynamics – elimination of constrained forces – Lagrangian multipliers – state space representation – algorithm and sparse matrix implementation. Spatial dynamics – Euler angles – Dynamic equations of motion – constrained dynamics – Newton Euler equations – linear and angular momentum.

TEXT BOOKS/REFERENCES:

1. Shabana A. A., "*Computational Dynamics*", Third Edition, John Wiley, 2010.
2. Shabana A. A., "*Dynamics of Multibody Systems*", Third Edition, Cambridge University Publications, 2005.
3. Nikravesh P. E., "*Planar Multibody Dynamics-formulation, Programming and Applications*", CRC Press, 2007.
4. Nikravesh P. E., "*Computer Aided Analysis of Mechanical Systems*", Prentice Hall, 1988.

16ED722 BIOMECHANICS 3-0-0-3

Elements of viscoelasticity, viscoelasticity models for the mechanical behaviour of biological tissues, creep and stress relaxation behavior for a basic viscoelastic material model. Structure, properties and mechanics of soft and hard tissues (bones, cartilage, muscles, tendon and ligaments), Analysis of stresses and strains in skeletal tissues, Anatomical positions, planes and axes, Segments of human body: segmental parameters, centre of mass and centre of gravity. Biomechanical analysis of human motion: linear and angular kinematics, linear and angular kinetics. Classification of joints, Mechanics of joints in lower and upper extremities, Mechanics of spine. Estimation of muscle forces, Joint reaction forces and moments. Computational modeling, design and analysis of artificial joints, implants, prosthesis, and orthosis.

TEXT BOOKS/REFERENCES:

1. Margareta Nordin, Victor H. Frankel, "*Basic Biomechanics of Musculoskeletal System*", Fourth Edition, Lippincott, Williams & Wilkins, 2012.
2. Bruce R. Martin, David B. Burr, Neil A. Sharkey, David P. Fyhrie, "*Skeletal Tissue Mechanics*", Second Edition, Springer, 2015.
3. Susan J. Hall, "*Basic Biomechanics*", Sixth Edition, McGraw-Hill, 2011.
4. Nihat Ozkaya, Margareta Nordin, David Goldsheyder, Dawn Leger, "*Fundamentals of Biomechanics - Equilibrium, Motion, and Deformation*", Third Edition, Springer, 2012.
5. Ming Zhang and Yubo Fan, "*Computational Biomechanics of the Musculoskeletal System*", CRC Press, 2014.

16ED723 PIPING AND PRESSURE VESSEL DESIGN 3-0-0-3

Piping - Introduction to piping Codes and Standards - Flow diagram - Basic Design of Piping Systems (material selection, pressure class, pipe size and thickness) and the components - Head losses due to pipes, valves & fittings – Darcy Weisbach and Hazen Williams equations and its applications - Piping layout and piping stress analysis – Allowable stresses - Flexibility factor and stress intensification factor – Two phase flow – Water hammer – Steam hammer – Piping Vibrations - Types of piping supports and their behavior. Pressure Vessel Design - Classification - Factors influencing the design of vessels - Material selection - Introduction to ASME cods for pressure vessel design, Pressure vessel and related components' design using ASME codes - Membrane stresses in pressure vessel under internal pressure and its application to shells (cylindrical, conical and spherical) and end closures - Thermal stresses - Buckling phenomenon - Elastic Buckling of circular ring and cylinders under external pressure - collapse of thick walled cylinders or tubes under external pressure - Effect of supports on Elastic Buckling of Cylinders - Design of circumferential stiffeners - Buckling under combined External pressure and axial loading - Design of saddle supports – Allowable nozzle loads and moments - Reinforcement requirements.

TEXT BOOKS/REFERENCES

1. Mohinder L. Nayyar, "*Piping Handbook*", McGraw Hill Handbook, Seventh Edition, 1999.

2. M. W. Kellogg Company, “*Design of Piping Systems*”, 2009.
3. Crane Co., “*Flow of Fluids Through Valves, Fittings and Pipe*”, Crane Technical Paper No. 410.
4. John F. Harvey, “*Theory and Design of Pressure Vessels*”, CBS Publishers and Distributors, 1985.
5. Somnath Chattopadhyay, “*Pressure Vessel Design and Practice*”, CRC press, 2004.
6. Henry H. Bednar, “*Pressure Vessel Design Hand Book*”, CBS Publishers and Distributors, 1990.
7. ASME Boiler and Pressure Vessel Code, Section II (Part D) and Section VIII (Division 1 & 2).
8. ASME Code for Pressure Piping, Power Piping ASME B31.1 & Process Piping ASME B31.3.
9. ASME B36.10M Welded and Seamless Wrought Steel Pipe.
10. Indian Boiler Regulations – 1950.

16ED724 NON-LINEAR FINITE ELEMENT METHOD 3-0-0-3

Sources of nonlinearities in structural problems: material, geometry, loads, boundary conditions; General features of nonlinear response: equilibrium trajectories, path dependencies, critical points; Geometrically nonlinear finite elements: residual and incremental forms. Finite element total Lagrangian and co-rotational formulations, FEM nonlinear equilibrium equations: initial stress, tangent and secant stiffness, geometric stiffness; Solution of nonlinear equations: classification, incremental control techniques, augmented equation methods, incremental and pseudo-force methods, Newton Methods, Secant (quasi-Newton) methods, Acceleration and line search, dynamic relaxation, determination and transversal of critical points. Computer implementation: model definition, element level calculation, equation assembly, nonlinear equation solver, residual evaluation, post-processing, Non-linear constitutive models, Applications to structural stability analysis and bifurcations, nonlinear static analysis and nonlinear transient problems (implicit vs. explicit time integration techniques), Treatment of constraints.

TEXT BOOKS/REFERENCES:

1. Reddy J. N., “*An Introduction to Nonlinear Finite Element Analysis*”, Oxford University Press, 2004.
2. Belytschko T., Liu W. K., and Moran B., “*Nonlinear Finite Elements for Continua and Structures*”, John Wiley and Sons, 2000.
3. Simo J. C. and Hughes T. J. R., “*Computational Inelasticity*”, Springer, 1998.
4. Hughes T. J. R., “*The Finite Element Method: Linear Static and Dynamic Finite Element Analysis*”, Dover Publications, 2000.

16ED725 INTRODUCTION TO NONLINEAR DYNAMICS AND CHAOS 3-0-0-3

Introduction and Motivation - Examples of Nonlinear and Chaotic Systems, definition of dynamical system, state space, vector field and flow; One Dimensional Flows – Flows on the line, fixed points and their stability, linear stability analysis, impossibility of oscillations, bifurcations in one dimensional case, saddle-node, transcritical and pitchfork, flows on the circle, examples. Two Dimensional Flows - Planar linear systems, solving linear systems, eigenvalues and eigen vectors, dynamical classification based on eigenvalues, planar nonlinear systems, phase portraits, linearisation, hyperbolic fixed points and Hartman-Grobman theorem, stable, unstable and centre manifolds, limit cycles, van der pol equation, Poincare-Bendixson theorem, saddle-node, transcritical, pitchfork and Andronov-Hopf bifurcations in planar case. Chaotic Dynamics - One dimensional maps, fixed points and cobwebs, logistic map, bifurcations in iterated maps and chaos, Feigenbaum universality. Three dimensional systems, Poincare sections, quasiperiodicity, routes to chaos. Quantifying chaos - Lyapunov exponents, Kolmogorov Sinai entropy, fractal dimensions. Analytical methods for nonlinear systems - Perturbation method, Secular terms, Lindsted - Poincare method, averaging method, method of multiple scales.

TEXT BOOKS/REFERENCES:

1. Steven H. Strogatz, "*Nonlinear Dynamics and Chaos*", Reading, Addison-Wesley, 1994.
2. Robert C. Hilborn, "*Chaos and Nonlinear Dynamics*", Section Edition, Oxford University Press, 2000.
3. Ali Hasan Nayfeh, "*Introduction to Perturbation Techniques*", John Wiley, 1993.
4. Morris W. Hirsch, Stephen Smale, and Robert L. Devaney, "*Differential Equations, Dynamical Systems and an Introduction to Chaos*", Academic Press, Elsevier, 2004.
5. Lakshmanan M. and Rajashekhar S., "*Nonlinear Dynamics*", Springer Verlag, 2003.
6. Robert L. Devaney, "*An Introduction to Chaotic Systems*", Second Edition, West View Press, 2003.
7. Edward Ott, "*Chaos in Dynamical Systems*", Cambridge University Press, 1993.