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
18MA610	FC	Optimization Techniques in Engineering	2-0-2	3
18ED601	FC	Advanced Mechanics of Solids	3-0-0	3
18ED651	SC	Failure Analysis and Design	3-0-0	3
18ED652	SC	Product Design and Quality Management	3-0-0	3
18ED653	SC	Mechanical Vibrations	3-0-0	3
18RM600	SC	Research Methodology	2-0-0	2
18ED661	SC	Engineering Design Lab-I	0-0-2	1
18HU601	HU	Amrita Values Program*		P/F
18HU602	HU	Career Competency I*		P/F
			Credits	18

***Non Credit Course**

SECOND SEMESTER				
Course Code	**Type**	**Course**	**L T P**	**Credits**
18ED654	SC	Design for Manufacturing and Assembly	3-0-0	3
18ED655	SC	Finite Element Techniques	3-0-0	3
18ED656	SC	Systems Engineering	2-0-0	2
	E	Elective I	3-0-0	3
	E	Elective II	3-0-0	3
	E	Elective III	3-0-0	3
18ED662	SC	Engineering Design Lab-II	0-0-2	1
18ED663	SC	Engineering Design Lab-III	0-0-2	1
18HU603		Career Competency II	0-0-2	1
			Credits	20

THIRD SEMESTER				
Course Code	**Type**	**Course**	**L T P**	**Credits**
	E	Elective IV	3-0-0	3
	E	Elective V	3-0-0	3
18ED798	P	Dissertation		8
			Credits	14

FOURTH SEMESTER				
Course Code	**Type**	**Course**	**L T P**	**Credits**
18ED799	P	Dissertation		12
			Credits	12

Total Credits 64

LIST OF COURSES

FOUNDATION CORE				
18MA610	FC	Optimization Techniques in Engineering	2-0-2	3
18ED601	FC	Advanced Mechanics of Solids	3-0-0	3

SUBJECT CORE				
18ED651	SC	Failure Analysis and Design	3-0-0	3
18ED652	SC	Product Design and Quality Management	3-0-0	3
18ED653	SC	Mechanical Vibrations	3-0-0	3
18RM600	SC	Research Methodology	2-0-0	2
18ED654	SC	Design for Manufacturing and Assembly	3-0-0	3
18ED655	SC	Finite Element Techniques	3-0-0	3
18ED656	SC	Systems Engineering	2-0-0	2

ELECTIVES			
18ED701	Fundamentals of Analytical Dynamics	3-0-0	3
18ED702	Nonlinear Vibrations	3-0-0	3
18ED703	Modelling, Simulation and Analysis of Engineering Systems	3-0-0	3
18ED704	Advanced Mechanism Analysis and Design	3-0-0	3
18ED705	Theory of Plasticity	3-0-0	3
18ED706	Tribology	3-0-0	3
18ED707	Product Lifecycle Management	3-0-0	3
18ED708	Theory of Plates and Shells	3-0-0	3
18ED709	Computational Fluid Dynamics	3-0-0	3
18ED710	Selection of Materials for Machine Design	3-0-0	3
18ED711	Mechanics of Composite Materials	3-0-0	3
18ED712	Random Vibrations	3-0-0	3

18ED713	Computer Aided Product Development	3-0-0	3
18ED714	Micro-Electro-Mechanical Systems	3-0-0	3
18ED715	Machine Condition Monitoring	3-0-0	3
18ED716	Design of Experiments	3-0-0	3
18ED717	Material Joining Techniques	3-0-0	3
18ED718	Bearing and Gear Design	3-0-0	3
18ED719	Mechatronics System Design	3-0-0	3
18ED720	Design Automation with IoT	3-0-0	3
18ED721	Reliability Engineering	3-0-0	3
18ED722	Multi-body Dynamics	3-0-0	3
18ED723	Bio-Mechanics	3-0-0	3
18ED724	Piping and Pressure Vessel Design	3-0-0	3
18ED725	Non-Linear Finite Element Method	3-0-0	3
18ED726	Introduction to Nonlinear Dynamics and Chaos	3-0-0	3
18ED727	Fracture Mechanics	3-0-0	3
18ED728	Experimental Stress Analysis	3-0-0	3
18ED729	Design Thinking	2-0-2	3
18ED730	Live in Lab*		3

*Students undertaking and registering for a Live-in-Lab project, can be exempted from registering for an Elective course.

**MOOC courses can be allowed in electives with suitable monitoring and assessment procedure.

PROJECT WORK			
18ED798	Dissertation		8
18ED799	Dissertation		12

18MA610 OPTIMIZATION TECHNIQUES IN ENGINEERING 2-0-2-3

Introduction to Optimization - Engineering applications - Statement of an optimization problem - Classification - Optimal problem formulation: Problems involving design and manufacturing - Optimality criteria - Classical optimization techniques - Kuhn-Tucker (KT) optimality conditions.
Non-linear programming: One dimensional minimization methods - Unconstrained optimization techniques - Constrained optimization techniques - Transformation methods - Interior and exterior penalty function method - Convergence and divergence of optimization algorithms - Complexity of algorithms.
Modern Methods in Optimization: Genetic Algorithm - Simulated Annealing - Particle Swarm Optimization - Neural Network based optimization - Optimization of Fuzzy systems - Multi-Objective optimization - Design of experiment based optimization - Data Analytics and optimization using Machine learning approach.
Implementing optimization algorithm using Matlab / Programming: Design optimization - Robust design - Optimization in manufacturing / machining – Multi objective optimization - Structural optimization - Shape optimization - Optimization in production planning and control.

TEXT BOOKS/ REFERENCES:

1. S.S. Rao, Engineering optimization: Theory and Practice, New age international, 3rd edition, 2013.
2. K. Deb., Optimization for Engineering Design: Algorithms and Examples, PHI, 2nd Edition, 2012.
3. J. S. Arora, Introduction to Optimum Design, Academic press, 4th Edition, 2017.
4. Saravanan. R., *"Manufacturing Optimization through Intelligent Techniques"*, Taylor & Francis, CRC Press, 2006.

18ED601 ADVANCED MECHANICS OF SOLIDS 3 0 0 3

Introduction to Continuum Theory & Continuum Approach: Vectors and Tensors, Stress Tensor & Principles, Kinematics of Deformation and Motion, Analysis of stress and strain, Mohr's circle for three dimensional stresses. Airy's stress function in rectangular and polar coordinates. Fundamental Laws and Equations.

Continuum Models in Solid Mechanics: Linear Elasticity: Elasto-Statistics and Elasto-Dynamics. Elasticity problems in two and three dimensions.

Energy method for analysis of stress, strain and deflection:
Theorem of virtual work, theorem of least work, Castiglioni's theorem, Rayleigh Ritz method, Galerkin's method, Elastic behavior of anisotropic materials like fiber reinforced composites.

Torsion of prismatic bars of solid section and thin walled section:
Analogies for torsion: Membrane analogy. Thin walled members of open cross section in which some sections are prevented from warping, Torsion of noncircular shaft.

Concept of shear center in symmetrical and unsymmetrical bending, stress and deflections in beams subjected to unsymmetrical bending, shear center for thin wall beam cross section, open section with one axis of symmetry, general open section, and closed section.

Stress in thick walled cylinder under internal and external pressure, Shrink fit compound cylinders, Stresses in rotating flat solid disk, flat disk with central hole, disk with variable thickness, disk of uniform strength.

TEXT BOOKS/ REFERENCES:

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

18ED651 FAILURE ANALYSIS AND DESIGN 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. Machine condition monitoring techniques and condition monitoring of gearboxes. 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.

6.Robert Bond Randall, "*Vibration-Based Condition Monitoring: Industrial, Aerospace and Automotive Applications*", John Wiley & Sons, 2011.

18ED652 PRODUCT DESIGN AND QUALITY MANAGEMENT 3 0 0 3

Need for developing products – the importance of engineering design – types of design –the design process – relevance of product lifecycle issues in design –designing to codes and standards- societal considerations in engineering design –generic product development process – various phases of product development-planning for products –establishing markets- market segments- relevance of market research

Identifying customer needs –voice of customer – Concept generation – testing of concepts – customer populations- hierarchy of human needs - need gathering methods – affinity diagrams – needs importance- establishing engineering characteristics-competitive benchmarking- - product design specification-case studies

Creative thinking –creativity and problem solving- creative thinking methods- generating design concepts-systematic methods for designing – functional decomposition – physical decomposition – functional representation –morphological methods- Decision making – Psychology of colors – Visual balancing – case studies

Quality Aspects of Design -Objectives and functions-Targets- Dimensions of Quality - quality function deployment- house of quality – GD&T - Measures and Matrices-Design of Experiments – design process - Identification of control factors, noise factors, and performance metrics – Quality tools – Case studies

Industrial design – human factors design –user friendly design – design for manufacturability - design for serviceability – design for environment – prototyping and testing – cost evaluation –categories of cost –overhead costs – activity based costing –methods of developing cost estimates – manufacturing cost –value analysis in costing – case studies & project

Design for reliability- basic concept of reliability- failure distributions- MTTF-MTBF-reliability of systems-redundancy-derating-maintainability- availability-reliability testing.

TEXT BOOKS/REFERENCES:

1. George E.Dieter, Linda C.Schmidt, "Engineering Design", McGraw-Hill International Edition, 4th Edition, 2009, ISBN 978-007-127189-9

2. Anita Goyal, Karl T Ulrich, Steven D Eppinger, "Product Design and Development ", 4th Edition, 2009, Tata McGraw-Hill Education, ISBN-10-007-14679-9

3. Kevin Otto, Kristin Wood, "Product Design", Indian Reprint 2004, Pearson Education,ISBN 9788177588217

4. Fundamentals of Quality control and improvement 4th edition, Amitava Mitra, Wiley, 2016.

5. Clive L.Dym, Patrick Little, "Engineering Design: A Project-based Introduction", 3rd Edition, John Wiley & Sons, 2009, ISBN 978-0-470-22596-7

6. Patrick D. T. O'Connor, " Practical reliability Engineering ", 4 th Edition, 2006,Wiley India Pvt Ltd.

18ED653 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.

18ED654 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.

18ED655 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.

18ED656 SYSTEMS ENGINEERING 2-0-0-2

Introduction to system Engineering - Need for systems Engineering, Overviews, Introduction to MBSE, Modeling Languages, Fundamentals of Modeling, Equivalence of Systems, Conjugate Power Variables, equivalent circuit representation - mechanical, electrical, hydraulic and acoustic. Lumped Element Modeling - cantilever beam, clamped plate, Helmholtz resonator and Crankshaft, Basic Elements - open modelica/Simulink, Lumped Element Modeling (two port network modeling) –

hydraulics and acoustics. Multibody Dynamics - linkage mechanism, Quarter Car Model & Half Car model. Solving flow and thermal problems using system simulation tools. Future of Systems Engineering

TEXT BOOKS/REFERENCES:

1. INCOSE. Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. *4*th ed. Wiley, 2015, p. 304. ISBN: 9781118999400.
2. NASA Headquarters. NASA Systems Engineering Handbook, NASA/SP-2007–6105 Rev 1. *Military Bookshop, 2007. ISBN: 9781780391380.*
3. Alexander Kosiakoff, William N. Sweet, Samual J. Seymour, Steven M.Biemer, Systems Engineering Principles and practice,2nd Edition, Wiley,2011

18ED661 ENGINEERING DESIGN LAB-I 0-0-2-1

Practical Stress Analysis:
Verification of stresses under mechanical loading using strain gauges, Calibration of torsional load cell.
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; Simulation of mode shapes using software packages.

18ED662 ENGINEERING DESIGN LAB-II 0-0-2-1

Mechanism Modeling and Analysis Lab:
Design and synthesis of simple mechanisms using synthesis tools, Force analysis of simple Mechanisms. Multi body dynamics.
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.

18ED663 ENGINEERING DESIGN LAB-III 0-0-2-1

Computational Fluid Dynamics:
Exercises covering computational fluid dynamics simulations involving meshing, internal flow, external flow over bluff bodies and flat plate, flow through nozzle, flow with heat transfer (covection & radiation). Basics of open source code-Open Foam.

18RM600 RESEARCH METHODOLOGY 2-0-0-2

Unit I:

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:
Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Unit III:
Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Unit IV:
Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents

Unit V:
Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science

TEXT BOOKS/ REFERENCES:

1. Bordens, K. S. and Abbott, B. B., "Research Design and Methods – A Process Approach", 8th Edition, McGraw-Hill, 2011
2. C. R. Kothari, "Research Methodology – Methods and Techniques", 2nd Edition, New Age International Publishers
3. Davis, M., Davis K., and Dunagan M., "Scientific Papers and Presentations", 3rd Edition, Elsevier Inc.
4. Michael P. Marder," Research Methods for Science", Cambridge University Press, 2011
5. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age". Aspen Law & Business; 6 edition July 2012

18ED701 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, 2012.
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, 2008.
5. Haim Baruh, "*Analytical Dynamics*", McGraw Hill International, 1999.

18ED702 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, 2008
2. Hayashi C., "*Nonlinear Oscillations in Physical Systems*", McGraw-Hill, 2014.
3. Thomsen J. J., "*Vibrations and Stability, Advanced Theory, Analysis and Tools*", Springer, 2003.
4. Nayfeh A. H. and Balachandran B., "*Applied Nonlinear Dynamics*", Wiley, 2008.
5. Seydel R., "*From Equilibrium to Chaos: Practical Bifurcation and Stability Analysis*", Elsevier, 1988.

18ED703 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.

18ED704 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, 2016.
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., 2018.

18ED705 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, 2013.
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, 1994.
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.

18ED706 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*", S. Chand & Company Ltd., 2008.
2. Bharat Bhushan, "*Introduction to Tribology*", John Wiley & Sons, 2013.

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.

18ED707 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, 2002.
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, 2000.

18ED708 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, 2017.
3. Chandrashekhara K., "*Theory of Plates*", Universities Press, 2001.

18ED709 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", Third Edition, Taylor & Francis, 2012.
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.

18ED710 SELECTION OF MATERIALS FOR MECHANICAL DESIGN 3-0-0-3

Overview of materials properties for Design, Overview of design principles,- mechanical, thermal, oxidation, corrosion, wear, creep and fatigue. Classification of materials - metals, ceramics, glasses, polymers, elastomers, composites, foams, advanced materials such as nano

materials, smart materials and aerospace materials. 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.

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.

18ED711 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, 2008.
2. Robert M. Jones, "*Mechanics of Composite Materials*", Second Edition, Taylor and Francis, 1999.
3. Halpin J. C., "*Primer on Composite Materials Analysis*", Techomic, 1992.
4. Mallick P. K. and Newman S., "*Composite Materials Technology - Processes and Properties*", Hansen, 1991.
5. Agarwal B. D. and Broutmen L. J., "*Analysis and Performance of Fibre Composites*", John Wiley & Sons, 2017.

18ED712 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, 2004.
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.

18ED713 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, 2010.

18ED714 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, 2010.
5. John A. Pelesko and David H. Bernstein, "*Modeling MEMS and NEMS*", First Edition, CRC; 2002.

18ED715 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*", Fourth Edition, PHI, 2007.
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.

18ED716 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, 2014.
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, 2005.
5. Mark J. Anderson and Patrick J. Whitcomb, "*DOE Simplified: Practical Tools for Effective Experimentation*", Third Edition, Productivity Press, 2015.

18ED717 MATERIAL JOINING TECHNIQUES 3-0-0-3

Joining techniques**,** Welding processes and grouping, welding terms.

Plasma, electron emission and ionization potential, arc temperature, influence of magnetic fields on arcs, arc blow, metal transfer, effect of polarity, effect of gases.

Power source characteristics, static and dynamic characteristics, CC and CV power source designs, current and voltage relationships, solid state power sources.

Detailed description about the process equipment, control of parameters, consumable, specifications for electrodes and filler metals and applications related to the following processes: Shielded metal arc welding, gas metal arc welding, flux cored arc welding, gas tungsten arc welding, plasma arc welding, submerged arc welding, stud arc welding.

Oxy-fuel gas welding, Electro Slag Welding, Resistance welding, Electron Beam Welding, Laser beam Welding, thermit welding , solid state welding processes – friction welding, friction stir welding, explosive welding, ultrasonic welding, diffusion welding. Weld overlay, thermal cutting and thermal spraying. Brazing and Soldering.

Heat transfer in weldments, dissipation of welding heat, cooling rates, weld metal cooling curves, peak temperature, calculating width of heat affected zones, solidification rate and effects of heat input.

TEXT BOOKS/ REFERENCES:

1. ASM Metals Hand Book, Vol 6, "Welding, Brazing and Soldering", ASM International, Metals Park, Ohio, 1993
2. Nadkarni S V “Modern Arc Welding Technology”, Oxford IBH Publishers, 1996.
3. AWS Welding Handbook, Volume 1, Welding Science & Technology, American Welding Society, 2001
4. Howard B Cary "Modern Welding Technology", Prentice Hall, New Jersey, 2002
5. Parmar, R.S, “Welding Engineering and Technology”, Khanna Publishers, 2003
6. AWS Welding Handbook, Volume 2, Welding Processes, Part 1, American Welding Society, 2004
7. AWS Welding Handbook, Volume 3, Welding Processes, Part 2, American Welding Society, 2004

18ED718 BEARING AND GEAR DESIGN 3-0-0-3

Bearing materials-Hydrodynamic real (finite) bearings-Design considerations in journal and thrust bearings-Hydrodynamic instability-Hydrodynamic and hydrostatic gas bearing.

Idealized slider and journal bearings-Oil flow and Thermal analysis of bearings-Bearing selection and design-Dynamically loaded bearings-Squeeze film bearings.

Gear fundamentals; Materials: steels, localized hardening of teeth, cast irons, nonferrous and nonmetallic; Force analysis and bearing loads: spur, helical and worm.

Gear Design: Fundamental design includes Lewis beam strength, Buckingham's dynamic load and wear load, corrections, characteristics and distribution, scoring, thermal limits, indexes of tooth loading, data needed for drawing and rating practice.

Gear box design: ray diagram, and kinematic layout.

TEXT BOOKS/REFERENCES:

1. Majumdar B. C., “Tribology of Bearings”, S. Chand & Company Ltd., 2008.
2. Bharat Bhushan, “Introduction to Tribology”, John Wiley & Sons, 2013.
3.Darle W Dudley, Handbook of Practical Gear Design,CRC Press LLC, 2002.
4.Gitin M Maitra, Handbook of Gear Design, 2nd Edition, Tata McGraw-Hill, 2003.
5.AGMA Standards Collection, American Gear Manufacturing Association, 2009.

18ED719 MECHATRONIC SYSTEM DESIGN 3-0-0-3

Mechatronic systems, Mechatronic design process, Traditional and Mechatronics designs, Advanced approaches in Mechatronics system, Industrial design and ergonomics.

Real-time interfacing, Elements of data acquisition and control, Overview of I/O process, Analog signals, discrete signals and Frequency signals.

Simulation basics, Probability concepts in simulation, Discrete event simulation, Simulation Methodology, Queuing system model components,Continuous system modelling,Monte Carlo simulation, Analysis of simulation results,Simulation life cycle.

Case studies of design of mechatronic products: Motion control using D.C.Motor & Solenoids,Car engine management systems.

Applications in Mechatronics: Sensors for condition based maintenance,Mechatronic Control in IoT based system,Artificial intelligence in Mechatronics,Machine Learning Applications in Mechatronics.

TEXT BOOKS/ REFERENCES:

1. Bolton, "Mechatronics – Electronic control systems in mechanical and electrical engineering, 2nd edition, Addison Wesley Longman Ltd., 2009.
2. Brian morriss, "Automated manufacturing Systems – Actuators Controls, sensors and Robotics", McGraw Hill International Edition, 2000.
3. Bradley, D. Dawson, N.C.Burd and A.J. Loader, "Mechatronics: Electronics in product and process", Chapman and Hall, London, 1999.
4. Klaus Janschek, "Mechatronic Systems Design", Springer publisher, 2012.

18ED720 DESIGN AUTOMATION WITH IoT 3-0-0-3

Introduction to IoT & Cyber-Physical Systems, IoT Enabling Technologies – Physical End points, Network Services, Cloud.Different Levels of IoT Applications.

Communication and networking technologies in IoT:Communication models, AdHoc. Industrial & Automotive Networks,Vehicular networks

Sensors and Actuators: Categorization based on complexity ,Introduction with applications , IR/Ultrasonic proximity & distance measurement, Accelerometers,Gyroscope, magnetometer, Acoustic Sensors, Multi sensor fusion.Motion control, motor control, relays , solenoid valve, IP based control. Control of Actuators via Internet, Cloud based control.

IoT implementation in Transportation and logistics, Energy and utilities, Automotive Connected supply chain, Plant floor control automation, remote monitoring, Management of critical assets, and proactive maintenance. Applications HCI and IoT world -Multilingual interactions Robotics and Autonomous Vehicles Sensing and data processing-Simultaneous mapping and localization-Levels of autonomy, Smart factories, Future research challenges.

TEXT BOOKS/ REFERENCES:

1. Adrian McEwan and Hakim Cassimally, "Designing the internet of things", Wiley, 2013
2. Vijay Madisetti and Arshdeep Bahga,"Internet of Things (A Hands-on-Approach)",1st Edition, VPT, 2014

3. Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stamatis Karnouskos, Stefan Avesand, David Boyle, "From Machine-to-Machine to the Internet of Things -Introduction to a New Age of Intelligence" Elsevier
4. Francis daCosta,"Rethinking the Internet of Things: A Scalable Approach to Connecting Everything",1st Edition, Apress Publications, 2013

18ED721 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, 2010.
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, 2017.
5. Srinath L. S., "*Reliability Engineering*", Fourth Edition, East West Publishers, 2005

18ED722 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*", Fourth Edition, Cambridge University Publications, 2013.

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.

18ED723 BIO-MECHANICS 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*", Seventh Edition, McGraw-Hill, 2014.
4. Nihat Ozkaya, Margareta Nordin, David Goldsheyder, Dawn Leger, "*Fundamentals of Biomechanics - Equilibrium, Motion, and Deformation*", Fourth Edition, Springer, 2016.
5. Ming Zhang and Yubo Fan, "*Computational Biomechanics of the Musculoskeletal System*", CRC Press, 2014.

18ED724 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, 1991.
5. Somnath Chattopadhyay, "*Pressure Vessel Design and Practice*", CRC press, 2007.
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.

18ED725 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, 2015.
2. Belytschko T., Liu W. K., and Moran B., "*Nonlinear Finite Elements for Continua and Structures*", John Wiley and Sons, 2013.
3. Simo J. C. and Hughes T. J. R., "*Computational Inelasticity*", Springer, 2006.
4. Hughes T. J. R., "*The Finite Element Method: Linear Static and Dynamic Finite Element Analysis*", Dover Publications, 2000.

18ED726 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,2000.
2. Robert C. Hilborn, "*Chaos and Nonlinear Dynamics*", Section Edition, Oxford University Press, 2000.
3. Ali Hasan Nayfeh, "*Introduction to Perturbation Techniques*", John Wiley, 2011.
4. Morris W. Hirsch, Stephen Smale, and Robert L. Devaney, "*Differential Equations, Dynamical Systems and an Introduction to Chaos*", Academic Press, Elsevier, 2012.
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, 2002.

18ED727 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*", Third Edition, CRC Press, 2005.
2. Suresh S., "*Fatigue of Materials*", Second Edition, Cambridge University Press, 2012.
3. Barsom J. M. and Roffe S. T., "*Fracture and Fatigue Control in Structures*", Third Edition, Englewoods Cliffs, Prentice Hall, 1999.
4. Broek D., "*Elementary Engineering Fracture Mechanics*", Fourth Edition, Martinus Nijhoff, 1987.
5. Knott J. K., "*Fundamentals of Fracture Mechanics*", Third Edition, Butterworth Heinemann, 2011.

18ED728 EXPERIMENTAL STRESS ANALYSIS 3-0-0-3

Strain gauges - mechanical, optical, acoustic, pneumatic and electrical strain gauges- strain measurement-Electrical resistance strain gauges-Wheat stone bridge, Strain gauge rosettes-Semiconductor strain gauges-Photo-elasticity, stress optic law, stress freezing technique-Fringe sharpening-Methods of slicing-Separation of principle stresses-Scattered light photo-elasticity-Moire fringe method-Separation of isochromatic and isopachic fringe pattern-Theory of photo elastic coating, -crack detection methods-Brittle coating method – Isostatics and isoentacties.

TEXT BOOKS/REFERENCES:

1. J.W. Dally and M.F. Riley, "Experimental Stress Analysis", McGraw-Hill Book Co., New York, 1988.
2. Srinath,L.S., Raghava,M.R., Lingaiah,K. Gargesha,G.,Pant B. and Ramachandra,K. – Experimental Stress Analysis, Tata McGraw Hill, New Delhi, 1984
3. P. Fordham, "Non-Destructive Testing Techniques" Business Publications, London, 1988.
4. M. Hetenyi, "Handbook of Experimental Stress Analysis", John Wiley & Sons Inc., New York, 1980.
5. G.S. Holister, "Experimental Stress Analysis, Principles and Methods", Cambridge University Press, 1987.

18ED729 DESIGN THINKING 3-0-0-3

Design process: Traditional design, Design thinking, Existing sample design projects, Study on designs around us, Compositions/structure of a design,
Innovative design: Breaking of patterns, Reframe existing design problems, Principles of creativity
Empathy: Customer Needs, Insight-leaving from the lives of others/standing on the shoes of others, Observation

Design team-Team formation, Conceptualization: Visual thinking, Drawing/sketching, New concept thinking, Patents and Intellectual Property, Concept Generation Methodologies, Concept Selection, Concept Testing, Opportunity identification
Prototyping: Principles of prototyping, Prototyping technologies, Prototype using simple things, Wooden model, Clay model, 3D printing; Experimenting/testing.
Sustainable product design, Ergonomics, Semantics, Entrepreneurship/business ideas, Branding, Advertising.
Product Data Specification, Establishing target specifications, Setting the final specifications.
Design projects for teams.

TEXT BOOKS/ REFERENCES:

1. Tim Brown, Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation, HarperCollins Publishers Ltd.
2. Idris Mootee, Design Thinking for Strategic Innovation,2013, John Wiley & Sons Inc
3. Brenda Laurel Design Research methods and perspectives MIT press 2003
4. Terwiesch, C. & Ulrich, K.T., 2009. Innovation Tournaments: creating and identifying Exceptional Opportunities, Harvard business press.
5. Ulrich & Eppinger, Product Design and Development, 3rd Edition, McGraw Hill, 2004
6. Stuart Pugh, Total Design: Integrated Methods for Successful Product Engineering,
7. Bjarki Hallgrimsson, Prototyping and model making for product design, 2012, Laurence King Publishing Ltd
8. Kevin Henry, Drawing for Product designers, 2012, Laurence King Publishing Ltd