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**
MA605	FC	Linear Algebra, Differential Equations, and Optimization	4 0 0	4
ED600	FC	Continuum Mechanics	3 0 0	3
ED601	FC	Heat Transfer	3 0 0	3
ED650	SC	Applied Fluid Dynamics	3 0 0	3
ED651	SC	Mechanical Vibrations	3 0 0	3
ED661	SC	Engineering Design Lab-I	0 0 1	1
ED662	SC	Engineering Design Lab-II	0 0 1	1
HU601	HU	Cultural Education*		P/F
*Non Credit course			**Credits**	**18**

Second Semester				
Course Code	**Type**	**Course**	**L T P**	**Credits**
ED602	FC	Theory of Elasticity	4 0 0	4
ED652	SC	Reliability Engineering	3 0 0	3
ED653	SC	Finite Element Methods	3 0 0	3
ED654	SC	Fatigue, Fracture, and Failure Analysis	3 0 1	4
ED655	SC	Selection of Materials and Processes	3 0 0	3
ED663	SC	Engineering Design Lab-III	0 0 1	1
ED664	SC	Engineering Design Lab-IV	0 0 1	1
EN600	HU	Technical Writing*		P/F
*Non Credit course			**Credits**	**19**

Third Semester				
Course Code	**Type**	**Course**	**L T P**	**Credits**
	E	Elective I	3 0 0	3
	E	Elective II	3 0 0	3
ED799	P	Dissertation		10
			Credits	**16**

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

Total Credits: 65

LIST OF COURSES

Foundation Core

Course Code	Course	L T P	Cr
MA605	Linear Algebra, Differential Equations, and Optimization	4 0 0	4
ED600	Continuum Mechanics	3 0 0	3
ED601	Heat Transfer	3 0 0	3
ED602	Theory of Elasticity	4 0 0	4

Subject Core

Course Code	Course	L T P	Cr
ED650	Applied Fluid Dynamics	3 0 0	3
ED651	Mechanical Vibrations	3 0 0	3
ED652	Reliability Engineering	3 0 0	3
ED653	Finite Element Methods	3 0 0	3
ED654	Fatigue, Fracture, and Failure Analysis	3 0 1	4
ED655	Selection of Materials and Processes	3 0 0	3
ED661	Engineering Design Lab-I	0 0 1	1
ED662	Engineering Design Lab-II	0 0 1	1
ED663	Engineering Design Lab-III	0 0 1	1
ED664	Engineering Design Lab-IV	0 0 1	1

Electives

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

Project Work

Course Code	Course	Cr
ED799	Dissertation	10
ED799	Dissertation	12

MA605 LINEAR ALGEBRA, DIFFERENTIAL EQUATIONS, AND OPTIMIZATION 4-0-0-4

Linear algebra: Review of matrices and linear systems of equations.
Vector spaces and subspaces, Linear independence, Basis and dimensions, Linear transformations, Orthogonality, Orthogonal basis, Gram Schmidt Process, Least-Square applications.
Differential Equations: Review of Laplace Transform and Fourier series. Solutions ordinary differential equations and system of differential equations through Laplace transforms. Solutions of partial differential equations (one dimensional heat and wave equations) through Fourier series.
Optimization Techniques: Single variable optimization: Optimality criteria – bracketing methods – region elimination methods – point estimation method – gradient based methods. Multivariable optimization: Optimality criteria – unidirectional search – direct search methods – gradient based methods. Lagrangian and Kuhn-Tucker conditions.
Solving problems using Numerical Methods, Matlab Exercises.

TEXT BOOKS/ REFERENCES:

1. Howard Anton and Chris Rorrs, "*Elementary Linear Algebra*", Ninth Edition, John Wiley & Sons, 2000.
2. Erwin Kreyszig, "*Advanced Engineering Mathematics*", Ninth Edition, John Wiley & Sons, 2013.
3. William E. Boyce and DiPrima R. C., "*Elementary Differential Equations and Boundary Value Problems*", Ninth Edition, Wiley, 2008.
4. Kalyanmoy Deb, "*Optimization for Engineering Design: Algorithms and Examples*", Prentice Hall, 2002.
5. Singiresu S. Rao, "*Engineering Optimization: Theory and Practice*", Third Edition, New Age Publishers, 2003.

ED600 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, Buterworth 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.

ED601 **HEAT TRANSFER** **3-0-0-3**

Steady state Heat conduction : One dimensional heat conduction equation – general heat conduction – boundary and initial conditions- Heat generation in solids- generalized thermal resistance network – extended surface heat transfer. Multidimensional steady conduction – Analytical solutions, Numerical method of analysis. Unsteady Heat Conduction: Unsteady state conduction – Lumped heat capacity system, plane wall with convection, infinite cylinder & sphere with convection, semi-infinite solid. Convective heat transfer: Boundary layer theory – physical mechanism of convection- Flow over flat plates, cylinders and spheres. Flow over tubes and bank of tubes- Natural and forced convection – combined natural and forced convection. Design of heat exchangers: Types of heat exchangers-Standard Representation-classification – parallel flow and counter flow - LMTD, NTU methods. Design of Shell and Tube heat exchangers, Compact heat exchangers, and Plate type heat exchangers.

TEXT BOOKS/REFERENCES:

1. Incropera F. P. and DeWitt D. P., "*Fundamentals of Heat and Mass Transfer*", John Wiley and Sons, 1998.
2. Ozisik M. N., "*Design of Heat Exchangers, Condensers and Evaporators*", John Wiley, New York, 1985.
3. Bejan A., "*Heat Transfer*", John Wiley and Sons, 1995.
4. Ozisik M. N., "*Heat Transfer*", McGraw Hill, 1994.
5. Holman J. P., "*Heat and Mass Transfer*", Tata McGraw Hill, 2000.
6. Cengel Y. A., "*Heat Transfer- A Practical Approach*", McGraw Hill, 1998.

ED602 **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.

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.

ED650 APPLIED FLUID DYNAMICS 3-0-0-3

Review of vectors and tensors, fluid deformation, fluid element strain-material derivative, stress and strain tensors, vorticity, circulation, stream function, velocity potential. Lagrangian and Eulerian description, Reynolds transport theorem, Conservation laws, Constitutive equations, Differential equation for conservation of mass, momentum and energy. Exact solutions of Navier Stokes, Poiseuille flow, Hagen Poisuille flow, flow between rotating cylinders. Introductory vorticity dynamics. Laminar boundary layers, Wall shear and boundary layer thickness, Von Karman Momentum integral equations, boundary layer separation, wake, control of boundary layer transition. Fundamentals of turbulent flows, Onset of turbulence, laminar-turbulent transition, introduction to stability theory, Orr- Somerfield equation, chaos and turbulence, mechanisms of laminar – turbulent transition, spectra and eddies, Kolmogorov length scale, mean motions and fluctuations, continuity equation, Reynolds equations, turbulent shear stress and closure problem, Prandtl's mixing length, Turbulence models. Pipe flows, single pipes and multiple pipe systems, fluid structure interaction, self excited vibration, flow induced vibrations, 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.

ED651 MECHANICAL VIBRATIONS 3-0-0-3

Introduction-Derivation of equation of motion-Free vibration of undamped single degree of freedom systems-Free vibration of damped single degree of freedom systems-Forced response of single degree of freedom systems-Rotating unbalance, support motion, whirling of shafts-Vibration isolation, vibration measuring instruments-Different types of damping-Response of s.d.o.f systems to arbitrary excitation-convolution integral, Fourier transforms method-Free vibration of undamped two degree of freedom systems-formulation and solution of matrix Eigen value problem, natural modes-Elastic and mass coupling, orthogonality of modes, natural coordinates-Response of two-d.o.f systems to harmonic excitation-Damped and undamped vibration absorbers-Matrix formulation for multi degree of freedom systems, influence coefficients- Undamped free vibration of multi-d.o.f systems, formulation of Eigen value problem-Orthogonality of modal vectors, expansion theorem-Solution of eigen value problem by characteristic determinant-Free vibration of continuous systems, Eigen value problem-Axial vibration of rods, bending vibration of bars-Natural modes of a bar in bending vibration-Introduction to the computational methods, solution of Eigen value problem by matrix iteration, power method using matrix deflation-Introduction to the classical methods for the solution of vibration problems-Rayleigh method, Dunkerleys equation, Lagrange’s equation.
Lab**:** Solving Vibration Problems using MATLAB.

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.

ED652 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-physical reliability models-random stress and random strength-static models-dynamic models-periodic loads-random loads-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-parameter estimation.

TEXT BOOKS/ REFERENCES:

1. Charles Ebeling, "*An Introduction to Reliability and Maintainability Engineering*", Tata McGraw Hill, 2000.
2. Richard E. Barlow and 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.

ED653 FINITE ELEMENT METHODS 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. Jacob Fish and Ted Belytschko, "*A First Course in Finite Elements*", Wiley Inter Science, 2007.

ED654 FATIGUE, FRACTURE, AND FAILURE ANALYSIS 3-0-1-4

Introduction, Macroscopic Mechanical Failure Modes, Historical overview. History of fatigue failures, Terminologies, Fatigue fracture surfaces and macroscopic features, microscopic aspects and Fatigue Mechanism, Crack nucleation, Crack growth, Fatigue failure. Testing and Specimens, S-N curves, Effect of Mean Stress, factors influencing fatigue life, Multiaxial and Variable amplitude loading. Monotonic and Cyclic stress strain behavior, Strain controlled tests, cyclic $\sigma - \varepsilon$ curves, Strain-Life (ε –**N**) approach, and factors influencing ε-N behavior. Mechanics of Fracture, Linear Elastic Fracture Mechanics (LEFM) and Elastic Plastic Fracture Mechanics (EPFM), Modes of Fracture, stress analysis of cracks; stress intensity factor (K), state of plane stress and plane strain; plastic zone, strain energy release rate (G), crack tip plasticity, crack resistance (R), practical use of the R-curve, LEFM Testing, standards, various specimen configurations (CT, SENB and CNT specimens). EPFM, history and limitations, J integral, COD and the CTOD, Dugdale's method; The design curve; Relationship between J-integral and COD. Fatigue Crack Growth Curves, damage accumulation, stable crack propagation, Relationships (Paris Power Law, Forman) - Closure Effects, Short Cracks, Stress Raisers; Threshold for crack propagation, Metallurgical/material factors affecting fatigue behaviour of engineering material, Effects of Notches, Residual stress, Variable amplitude and Multi-Axial Loading, Other Conditions. Failure Analysis introduction, Principles and benefits, knowledge base and common facilities required for performing failure analysis, introduction to typical steps taken in carrying out failure analysis, Techniques of failure analysis, Service failure mechanisms and Case studies.

TEXT BOOKS/REFERENCES:

1. Stephens I., Fatemi A., Stephens R. R., and Fuchs H. O., "*Metal Fatigue in Engineering*", Second Edition, John Wiley & Sons Inc., 2001.
2. Anderson, T. L., "*Fracture Mechanics: Fundamentals and Applications*", Second Edition, Taylor & Francis, 1994.
3. Hertzberg R. W., "*Deformation and Fracture Mechanics of Engineering Materials*", John Wiley & Sons, 1996.
4. Broek D., "*Elementary Engineering Fracture Mechanics*", Second Edition, Sÿthoff and Nordhoff Int. Publications, 1983.
5. Suresh S., "*Fatigue of Materials*", Second Edition, Cambridge University Press, 1998.
6. Knott J. F., "*Fundamentals of Fracture Mechanics*", Butterworth & Co., Ltd., London, 1983.
7. Brooks C. R. and Choudhury A., "*Failure Analysis of Engineering Materials*", McGraw-Hill, 2002.

ED655 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. Design of components - functions, constraints, objectives and free variables. 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 processing, 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, Additive Manufacturing Techniques.

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.

ED661 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. Exercises involving customization of CAD software using VB programming.
Geometric Dimensioning and Tolerancing: Simple exercises involving GD&T.
Computational Methods**:** Solving system of linear equations, curve fitting using Matlab, Solving ODE's and PDE's using Matlab toolbox, Programming using Matlab.

ED662 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.

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

Experimental Engineering Lab
Design of Experiments:
Introduction to Design of Experiments, Factorial Design, Response Surface Methods.
Practical Stress Analysis:

Verification of stresses under mechanical loading using strain gauges, Calibration of torsional load cell, Modal testing and extraction of modal parameters.
Machine Condition Monitoring:
Machine condition monitoring studies using FFT analyzer and virtual instrumentation tools.

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

Six-Sigma and Reliability Engineering Lab
Reliability testing, Implementation of Six Sigma concepts.
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.
Mechanism Modeling and Analysis Lab:
Design and synthesis of simple mechanisms using synthesis tools, Force analysis of simple mechanisms.

EN600 TECHNICAL WRITING P/F

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.) - Oral presentations.

TEXTBOOKS / REFERENCES:

1. Hirish H L, *Essential Communication Strategies for Scientists, Engineers and Technology Professionals,* Second Edition, IEEE Press, New York, 2002
2. Anderson P V, *Technical Communication: A Reader-Centred Approach,* Sixth Edition. Cengage Learning India Pvt. Ltd., New Delhi, Reprint 2010.
3. Strunk Jr. W and White E B, *The Elements of Style,* Alliyan & Bacon, New York, 1999.

ED700 INTRODUCTION TO 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.

ED701 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*", Second 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.

ED702 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.

ED703 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. Computer aided kinematic analysis - Euler parameters - Co-ordinates of a body, Identities with Euler parameters. Spatial Kinematics - Relative constraints between two vectors - Relative constraints between two bodies - Concept of equivalent mechanisms. Synthesis of mechanisms - Three position and four position synthesis - Chebyshev spacing of precision points - Computer aided synthesis. Curvature theory – Velocities and accelerations – Review of instant centre concept - Euler – Savary equations - Bobillier theorem - Cubic of stationary curvature - Ball's point. Review of basic concepts in dynamics - Planar dynamics - Equations of motion - System of equations of motion - Computer assisted dynamic force analysis of planar mechanisms. Kinematics of Robot - Introduction - Topology arrangements of robotics arms – Kinematic Analysis of Spatial RSSR mechanism - Denavit - Hartenberg Parameters - Forward and inverse Kinematics of Robotic Manipulators - 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.

ED704 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.

ED705 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.

ED706 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.

ED707 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.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.

ED708 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 unsymmetric 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 - ax symmetric 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.

ED709 COMPUTATIONAL FLUID DYNAMICS 3-0-0-3

Introduction: Conservation equation; 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 techniqies. Higher order schemes (QUICK algorithm). Discretization of incompressible flow equations. Pressure based algorithm: SIMPLE, SIMPLER etc.Introduction to turbulence modelling: Reynolds averaged Navier-Stokes equations, RANS modelling, 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.

ED710 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.

ED711 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-Whitness nuismer 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.

ED712 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.

ED713 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.

ED714 MICRO-ELECTRO-MECHANICAL SYSTEMS 3-0-0-3

Introduction: MEMS and Microsystems, Typical MEMS and microsystem products, evolution of micro-fabrication. Mechanics for Micro System Design: Static bending of thin plates, mechanical vibration – micro accelerometer- design theory- resonant micro sensors, thermo mechanics, and fracture mechanics- interfacial fracture mechanics, Finite element stress analysis. Thermo-fluid Engineering: Basic Equations in Continuum Fluid Dynamics, Fluid flow in Sub micrometer and nanoscale, Heat Conduction - multilayered thin films-solids in sub micrometer scale. Scaling Laws: Geometry, dynamics, electrostatic forces, electromagnetic forces, fluid mechanics and heat transfer. Micro System Fabrication Processes: Photolithography, Chemical vapour Deposition, Physical vapour Deposition, Etching- chemical, plasma, Bulk and Surface Micro Manufacturing, LIGA. Micro system packaging- levels- die preparation, surface bonding, wire bonding, sealing, -assembly of Microsystems- packaging materials, signal mapping and transduction.

TEXT BOOKS/REFERENCES:

1. Tai–Ran Hsu, "*MEMS and Microsystems Design and Manufacturing*", Tata McGraw Hill, 2002.
2. Marc J. Madou, "*Fundamentals of Microfabrication*", Second Edition, CRC Press, 2002.
3. Mohamed Gad-el-Hak, "*The MEMS Handbook*", CRC Press, 2002.

ED715 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 Hess and 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.

ED716 MANUFACTURING PROCESS TECHNOLOGY 3-0-0-3

Principles of fluid flow and heat transfer applied to solidification process in casting and welding. Heat transfer models for various casting processes-sand, die and investment moulding. Design of gating and riser using simulation of heat and fluid flow during mould filling and solidification. Design of die and mould cooling lines. Prediction of micro-porosity and shrinkage. Types of heat sources in fusion welding. Modelling of heat source-stationary and moving. Heat transfer models for transient and pseudo steady state welding processes. Prediction of heat flow and temperature distribution in fusion welding -GTA, GMA, Electro-slag, Laser and e-Beam processes. Prediction of bead geometry and heat affected zone. Thermal modelling of heat treatment processes- governing equations, prediction of cooling rate and its effect on the hardness and the mechanical properties. Surface modification- objectives, diffusion modelling, physical/chemical vapour deposition, plasma deposition, ion implantation. Types and applications of directed heat energy sources to surface modification-plasma, electron, and laser beams. Processing of metal and ceramic matrix composites-types of matrices and reinforcements, casting, infiltration, spray forming, diffusion bonding, and physical vapour deposition. Illustration of the principles with practical problems. Use of software packages in solving sample problems. Review of case studies.

TEXT BOOKS/ REFERENCES:

1. Kuang-O Yu, "*Modeling for Casting and Solidification Processing*", Marcel Dekker, 2002.
2. Grong O., "*Metallurgical Modelling of Welding*", Second Edition, The Institute of Materials, 1997.
3. Kou S., "*Transport Phenomena in Materials Processing*", John Wiley & Sons, 1996.
4. Griffths B., "*Manufacturing Surface Technology*", Taylor, 1996.
5. Clyne T. W. and Withers P. J., "*An Introduction to Metal Matrix Composites",* Cambridge Univ. Press, 1993.
6. Ilegbusi O. J., "*Materials and Physical Modeling of Materials Processing Operations*", Chapman & Hall, 2000.

ED717 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.

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