DEPARTMENT OF MECHANICAL & MANUFACTURING ENGINEERING, MIT Manipal

M.Tech. COMPUTER AIDED ANALYSIS & DESIGN

Program Structure (Applicable to 2019 admission onwards)

Year	FIRST SEMESTER						SECOND SEMESTER					
	Sub Code	**Subject Name**	**L**	**T**	**P**	**C**	**Sub Code**	**Subject Name**	**L**	**T**	**P**	**C**
I	MAT 5155	Applied Numerical Methods	3	1	0	4	MME 5283	Finite Element Methods	3	1	0	4
	HUM 5151	Research Methodology and Technical Communication	1	0	3	2	MME 5282	Lubrication of Bearings	3	1	0	4
	MME 5181	Advanced Mechanical Vibrations	3	1	0	4	MME ****	Elective I	3	1	0	4
	MME 5182	Fatigue of Materials	3	1	0	4	MME ****	Elective II	3	1	0	4
	MME 5183	Geometric Modeling for CAD	3	1	0	4	MME****	Elective III	3	1	0	4
	MME 5184	Solid Mechanics	3	1	0	4	*** ****	Open Elective	3	0	0	3
	MME 5168	CAD Lab	0	0	6	2	MME 5267	Finite Element Analysis Lab	0	0	6	2
	MME 5165	Design Engineering Lab	0	0	3	1						
		Total	**16**	**5**	**12**	**25**		**Total**	**18**	**5**	**6**	**25**
II	**THIRD AND FOURTH SEMESTER**											
	MME 6098	Project Work							0	0	0	25
								Total	0	0	0	**25**

PROGRAM ELECTIVES			
MME 5004	Computational Fluid Dynamics	MME 5016	Advanced Mechanisms and Design
MME 5013	Design for Manufacturing	MME 5017	Biomechanics
MME 5014	Fracture Mechanics	MME 5018	Rotor Dynamics
MME 5015	Mechanics of Composite Materials		

OPEN ELECTIVES			
MME 5053	Corrosion Science	MME 5057	Industrial Safety Engineering
MME 5054	Creativity for Product Design	MME 5058	Lean Manufacturing
MME 5055	Design of Experiments	MME 5059	Renewable Energy Technology
MME 5056	Energy Storage Systems		

SEMESTER I

MAT 5155: APPLIED NUMERICAL METHODS [3 1 0 4]

Interpolations, Numerical Differentiation and Integration, Solution of linear and nonlinear system of equations: direct methods and iterative methods, Eigen values & Eigen vectors using Power Method. Numerical Solution of Ordinary Differential Equations, Initial Value Problems: Single step methods. Multi step methods, Boundary Value Problems: Finite difference method. Numerical Solution of Partial Differential Equations, Elliptic P.D.E, Parabolic P.D.E, Hyperbolic P.D.E.

References:

1. Atkinson K. E: An Introduction to Numerical Analysis, edn 3, John Wiley and Sons (1989).
2. Carnahan, Luther and Wikes: Applied Numerical Methods, TMH, New edition (1969).
3. Hilderband F.B: Introduction to Numerical Analysis, Edn 5, Tata McGraw Hill, New Delhi, New edition
4. Conte S.D and Be Door, Introduction to Numerical analysis, McGraw Hill.
5. Gerald C.F. and Patrick D. Wheatley: Applied Numerical Analysis, 3rdedn. 1984, Addison Wesley.
6. J. W. Thomas, Numerical Partial Differential Equations: Finite Difference Methods, Springer Verlag.
7. G. D. Smith, Numerical Solution of Partial Differential Equations, Oxford Univeristy Press.
8. Jain, Iyengar and Jain: Numerical methods for Scientific and Engineering Computations, New Age Publishers.

HUM 5151: RESEARCH METHODOLOGY AND TECHNICAL PRESENTATION [1 0 3 2]

Mechanics of Research Methodology: Basic concepts: Types of research, Significance of research, Research framework, Case study method, Experimental method, Sources of data, Data collection using questionnaire, Interviewing, and experimentation. Research formulation: Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. Research hypothesis: Criterion for hypothesis construction, Nature of hypothesis, need for having a working hypothesis, Characteristics and Types of hypothesis, Procedure for hypothesis testing, Sampling methods- Introduction to various sampling methods and their applications. Data Analysis: Sources of data, Collection of data, Measurement and scaling technique, and Different techniques of Data analysis. Thesis Writing and Journal Publication: thesis writing, journal and conference papers writing, IEEE and Harvard styles of referencing, Effective Presentation, Copyrights, and avoiding plagiarism.

References

1. Dr Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, SAGE, 2005.
2. Geoffrey R. Marczyk, David DeMatteo & David Festinger, Essentials of Research Design and Methodology, John Wiley & Sons, 2004.
3. John W. Creswel , Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, SAGE, 2004
4. Suresh C. Sinha and Anil K. Dhiman, Research Methodology (2 Vols-Set), Vedam Books, 2006.
5. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International Publisher, 2008.
6. Donald R Cooper & Pamela S Schindler , Business Research Methods, McGraw Hill International, 2007.
7. R. Pannershelvam, Research Methodology, Prentice Hall, India, 2006
8. Manfred Max Bergman, Mixed Methods Research, SAGE Books, 2006.
9. Paul S. Gray, John B. Williamson, David A. Karp, John R. Dalphin, The Research Imagination, Cambridge University press, 2007.
10. Cochrain & Cox, Experimental Designs, II Edn. Wiley Publishers, 2006.

MME 5181: ADVANCED MECHANICAL VIBRATIONS [3 1 0 4]

Vibration fundamentals, Single degree freedom systems, damping, free and forced vibration, force transmissibility, vibration isolation, two degree freedom systems-dynamic vibration absorber, multidegree freedom system, whirling of shaft. Continuous systems, Finite element method, Standard and nonstandard eigenvalue problem, concept of iteration and methods, Rayleigh damping. Nonlinear vibration solution methods, subharmonic & super harmonic oscillations, graphical methods, stability of equilibrium states, limit cycles and chaos, Perturbation method, Duffing's system, VanderPol's systems. Random vibration: Gaussian random process, Fourier analysis, power spectral density, wide band and narrow band processes, response of a single degree of freedom system. Vibration Transducers, electrodynamic and linear variable differential transformer transducers; Vibration pickups, Exciters-mechanical exciters, electrodynamic shaker, Signal analysis: modulation, spectrum analysers, bandpass filter, dynamic testing of machines and structures, Experimental modal analysis, Machine condition monitoring and diagnosis.

References:

1. Singiresu S. Rao (2004) "Mechanical Vibrations" 4/e, *Pearson Education Inc.*
2. Ramamurti V. (2000) "Mechanical Vibration Practice with Basic Theory" *Narosa Publishing House*, Chennai
3. Rao J. S. and Gupta K. (1999) "Theory and Practice of Mechanical Vibrations" *New Age International Publishers*
4. Rao J. S. (1992) "Advanced Theory of Vibrations" *Wiley Eastern Limited*, Bangalore
5. Balakumar Balachandran and Edward B. Magrab (2004) "Vibrations" Thomson – Brooks/Cole
6. William T. Thomson (1988) "Theory of Vibrations with Applications" 3/e, *CBS Publishers & Distributors*, New Delhi

MME 5182: FATIGUE OF MATERIALS [3 1 0 4]

Structure and deformation of materials, strategies in fatigue design, fatigue design philosophies, Modes of mechanical failure, fatigue mechanisms and microscopic features, macro aspects of fatigue of metals. *Stress-life approach:* Stress-life (S-N) curves, fatigue limits, mean stress effects on S-N behavior, factors influencing S-N behavior, S-N curve representation and approximations, stress concentration effects, notch sensitivity factor, Life estimation using S-N approach. Cumulative damage theories and life prediction. *Cyclic deformation and Strain-life approach:* Monotonic stress-strain behavior, cyclic stress-strain behavior, cyclic stress-strain curve determination, stress-plastic strain power law relationship, fatigue crack initiation in ductile solids, cyclic deformation and crack initiation in brittle solids. Strain-life curve, determination of fatigue properties, transition life, mean stress effects and strain life equations, notch stresses and strains, notch strain analysis- Neuber's rule, fatigue testing procedures and statistical analysis of fatigue data. *Variable amplitude loading:* Fatigue from Variable amplitude loading – damage quantification, load interaction and sequence effects, cycle counting methods. *Multi-axial fatigue:* States of

stress and strain, proportional versus non-proportional loading, multi-axial theories.*Effect of temperature on fatigue:* Low-temperature fatigue, high-temperature fatigue, Thermo-mechanical fatigue. *Fatigue of weldments:* Stress-life & strain-life behaviors, improving fatigue resistance, life estimation. Fatigue life extension methods.

References:

1. Stephens Ralph I, Fatemi Ali, Stephens Robert R and Henry, *Metal Fatigue in Engineering*, (2e), John Wiley and Sons Inc, New York, 2001.
2. Norman E Dowling, *Mechanical Behaviour of Materials,* (4e), Prentice Hall, 2012.
3. Suresh S, *Fatigue of Materials*, (2e), Cambridge University Press., UK, 1998.
4. Julie A Bannantine, Jess J Comer and James L Handrock, *Fundamentals of Metal fatigue and Analysis*, Prentice Hall, 1990.
5. Jack A Collins, *Failure of Materials in Mechanical Design*, (2e), John Wiley & Sons., New York, 1993.

MME 5183: GEOMETRIC MODELING FOR CAD [3 1 0 4]

Hardware and software for Computer Aided Design (CAD), geometric modelling concepts of CAD; Mathematical representation in parametric form of analytic curves (line, circle, ellipse and hyperbola), synthetic curves (Hermite cubic splines, Bezier curves, B-spline curves, NURBS), analytical surfaces (plane, ruled, tabulated, revolved), synthetic surfaces (Bi-cubic, Bezier, B-spline, NURBS, Coons, Ferguson's and Bi-linear surface patches); Solid modeling techniques (Half spaces, Boundary representation, Constructive solid geometry, Sweep representation, Analytic solid modeling); rasterization of lines, circles and ellipse; 3D transformation (translation, scaling, rotation and concatenation) of geometric entities and their projections; principles of visual realism and mechanical assembly.

References:

1. Michael E. Mortenson, GEOMETRIC MODELING, Wiley Computer Publishing, John Wiley and Sons, Inc. (Second Edition), 1996.
2. Ibrahim K Zeid, *CAD/CAM Theory and Practice*, Tata McGraw Hill, New Delhi, 1998.
3. David F Rogers and J Alan Adams, *Mathematical Elements for Computer Graphics*, Tata McGraw Hill, New Delhi, 2002.
4. David F Rogers and J Alan Adams, *Procedural Elements for Computer Graphics*, McGraw Hill, New York, 2001.
5. Ram B, *Computer Fundamentals Architecture and Organization*, New Age International Ltd New Delhi, 2000.
6. Donald Hearn and M Pauline Baker, *Computer Graphics*, Prentice Hall of India, New Delhi, 2000.

MME 5184: SOLID MECHANICS [3 1 0 4]

Analysis of Stress: Deformable bodies, stress, strain, mechanical properties of solids, State of stress and stress components, Stresses on an arbitrary plane, Principal stresses, Octahedral stresses, Equations of equilibrium. Analysis of Strain: Deformation in the neighbourhood of a point, 3D strain components, Volumetric strain, Principal strains, Compatibility conditions. Stress-strain Relations: Generalized Hooke's law, Stress strain equations for isotropic materials, Young's modulus, modulus of rigidity, Bulk modulus. Theories of Failure: Maximum normal stress theory, maximum shear stress theory, maximum strain theory, maximum elastic energy theory, distortion energy theory, Factor of safety. Energy Methods: Hooke's Law and Principle of superposition, Corresponding forces and displacements, work done by forces and elastic strain energy, Reciprocal relations, Castigliano's theorems. Bending of Beams: Introduction, straight beams and axi-symmetrical bending, bending stresses. Axi-Symmetric Problems: Introduction, equilibrium equations, thick and thin cylinders.

References:

1. L.S. Srinath "Advanced Mechanics of Solids", Tata Mcgraw Hill, 1980.
2. S.M.A. Kazmi "Solid Mechanics", Tata Mcgraw Hill, 1980.
3. E.P. Popov "Introduction to Mechanics of solids", Prentice Hall of India, Ltd, 1973.
4. Y.C.Fung "Foundations of solid mechanics", Prentice Hall of India, 1968.
5. S.A.Urry and P.J.Turner "Solving problems in solid mechanics" – vol 1 and 2, Longman Scientific and technical U.K., 1986.
6. S.C.Goyal and M.R.Sethia " Mechanics of solids", Sandhya Prakashan – 1997.
7. N.Krishnaraja and D.R. Gururaja "Advanced Mechanics of solids and structures", Narosa Publishing House, 1997.

MME 5161: CAD LAB [0 0 6 2]

Construct geometrically constrained 2D objects; develop solid models of machine parts; develop surface models of engineering applications; assemble solid models of parts into machine components; develop the product drawings (orthographic, sectional and pictorial/isometric views) of assembled machine components

References:

1. Sham Tickoo, *CATIA – for Engineers and Designers* Dreamtech Press New Delhi, 2008.

MME 5165 DESIGN ENGINEERING LAB [0 0 3 1]

Friction and wear performance tests; Journal bearing characteristics; Lubricity and viscosity measurement; Surface roughness measurement; Air bearing performance testing; Determination of natural frequency of single DOF undamped, damped and torsional vibrations systems; Determination of critical speed of shaft; Determination of center of percussion, mass moment of inertia of irregular bodies; Frequency response of single DOF viscous damped forced vibration system; Natural frequency of continuous system; Modelling of equivalent spring-mass system; Field balancing of rotor system; Fatigue test; Time domain, frequency domain, time-frequency domain analysis of specific signals acquired from machinery; Basic study of Atomic Force Microscopy (AFM) in imaging and material characterization.

References:

1. Kenneth C Ludema, Friction, Wear, Lubrication: A Textbook in Tribology, CRC press, 1996.
2. GwidonStachowiak, Andrew Batchelor, Engineering Tribology, Elsevier, 4th ed., 2013.
3. Singirisu Rao S., "Mechanical Vibration" Pearson Education, Delhi, 2004
4. S. Graham Kelly,"Fundamentals of Mechanical Vibrations", McGraw-Hill, Singapore, 1993.
5. RudraPratap, "Getting Started with MATLAB", Oxford University Press, USA

SEMESTER II

MME 5283: FINITE ELEMENT METHODS [3 1 0 4]

Introduction: General procedure of FEM. Formulation Methods - Direct Method: Spring and truss elements, arbitrarily oriented elements, transformation matrix, plane truss. Energy Method: Principle of total minimum potential energy, Formulation of plane stress/strain elements. Galerkin's Weighted Residual Method: Beam theory, formulation of beam element, arbitrarily oriented beam elements, plane frame. Isoparametric Elements: Formulation of truss, plane and solid elements. Introduction to Analysis Types: Modal or frequency analysis, thermal analysis, thermo-structural analysis, axi-symmetric analysis, fluid flow analysis.

References:

1. Daryl L Logan, A First Course in Finite Element Method, Thomson Asia Pvt. Ltd, Bangalore, 2002.
2. Akin J.E., Finite Element Analysis for Undergraduates, Academic Press, London, 1989.
3. Martin H.C. and Carey G.F., Introduction to Finite Element Analysis, Tata McGraw Hill, New Delhi, 1975.
4. Segerlind L J., Applied Finite Element Analysis, John Wiley, New York, 1984.
5. Bathe K J, Finite Element Procedures, Prentice Hall of India New Delhi, 2003.
6. Cook Robert D, Concepts and Applications of Finite Element Analysis, John Wiley and Sons New York, 2000.

MME 5282: LUBRICATION OF BEARINGS [3 1 0 4]

Lubricants and their physical properties, lubricants standards, lubrication regimes, Hydrodynamic Lubrication Theory- Reynolds equation, Design of fluid film bearings, lubricant flow and delivery, Hydrodynamic instability. Elasto hydrodynamic lubrication, Hertzian stress equation, load capacity, stresses and deflection, bearing life calculation, rolling bearing failures. Computational hydrodynamics, Finite difference equivalent of the Reynolds equation, Numerical analysis of hydrodynamic lubrication in a real bearing. Hydrostatic lubrication: generalized approach to hydrostatic bearing analysis, Optimization of hydrostatic bearing design, Aerostatic bearings, Hybrid bearings, Stability of hydrostatic and aerostatic bearings. Solid lubrication: Lubrication by lamellar solids, Friction and wear characteristics of lamellar solids, Deposition methods of solid lubricants, Solid lubricants as additives to oils and polymers.

References:

1. Cameron A., *Basic Lubrication Theory*, Ellis Horwood Ltd, Chichester, 1983.
2. Majumdar B.C., *Introduction to Tribology of Bearings*, A H Wheeler & Co. Pvt. Ltd., Allahabad, 1999.
3. Williams J.A., *Engineering Tribology*, Cambridge University Press, UK, 2005.
4. Neale, M.J., *Tribology Hand Book*, Butterworth Heinemann, London, 1995.
5. Gwidon W. Stachowiak, Andrew W. Batchelor, *Engineering Tribology*, Butterworth Heinemann, London.

MME 5262: FINITE ELEMENT ANALYSIS LAB [0 0 6 2]

Model and carry out structural analysis of plane/space trusses, plane/space frames, 2D components, 3D components, shells and contact problems using the GUI of a standard FEA software; Write Macros/codes for developing mapped mesh for 2D and 3D boundary value problems and analyze the same; Carry out the modal, harmonic and contact analysis of structural problems; Model and carry out 2D/3D thermal analysis and thermo-structural problems; Write and execute scripts/programs for analyzing 1D problems, plane/space trusses, plane/space frames and 2D structural problems.

References:

1. Eliahu Zahavi (1992) "The Finite Element Method in Machine Design" Prentice Hall Inc USA.
2. Ramamurthy V (1997) "Computer Aided Mechanical Design and Analysis" Tata Mcgraw Hill Delhi.
3. Daryl L Logan (2002) "A First Course in the Finite Element Method" Thomson Asia Pvt. Ltd. Bangalore.
4. Tirupathi R. Chandrupatla and Ashok D. Belegundu (2012), "Introduction to Finite Element Engineering" 4th Edition, Pearson.
5. Rudra Pratap, "Getting Started with MATLAB", Oxford University Press, USA

PROGRAM ELECTIVES

MME 5004: COMPUTATIONAL FLUID DYNAMICS [3 1 0 4]

Models of Flow and derivation of governing conservation differential equations for different models for conservation of mass, momentum and Energy. Discussion of characteristics and Boundary and Initial conditions. Basic numerical methods to solve first diffusion related flow physics followed by Convective dominated Diffusion flows. Difficulties and strategies to solve such flows.Algorithmic approach and convergence as well as stability. Turbulence and related closure using turbulence modelling.

References:

1. John D Anderson Jr. (1995). "Computational Fluid Dynamics- The Basics with Applications", International Edition, McGraw Hill, New York.
2. Suhas V. Patankar, (1980). "Numerical Heat Transfer and Fluid Flow", Hemisphere / McGraw Hill, New York.
3. H. K. Versteeg and W. Malalasekera. (1995) "An Introduction to Computational Fluid Dynamics - The Finite Volume Method", Longman Scientific & Technical. England
4. Ghoshdastidhar. (1998) "Computer Simulation of Flow and Heat Transfer", Tata- McGraw-Hill Book Company, New Delhi
5. K. Muralidhar and T. Sundararajan (2003), "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi

MME 5013: DESIGN FOR MANUFACTURING [3 1 0 4]

Significance of design for manufacturing (DFM), factors influencing design, Selection of materials, Selection of manufacturing processes, Design for assembly, Design for serviceability, DFM of formed metal components-metal extrusions, metal stampings, cold extruded parts, roll formed sections, powder metallurgy parts, forging, metal injection molded parts, DFM of castings-sand casting, investment casting, die casting, DFM of machined components-turning, drilling, reaming, boring, milling, slotting, grinding, honing, lapping, superfinishing, advanced machining processes, gears and non metallic parts, Process engineering-designing for heat treatment, Sequence of operations for manufacturing of round and flat type components, Manufacturing drawings-dimensioning for manufacturing, fits, tolerance and surface finish consideration in design, preparation of manufacturing drawings of components.

References:

1. Geoffrey Boothroyd, Peter Dewhurst and Winston A. Knight, *Product Design for Manufacture and Assembly,* (3e), CRC Press, 2011.
2. James G. Brala, *Design for Manufacturability Handbook,* (2e), McGraw Hill, New York, 1999.

3. Kevin Otto and Kristin Wood, *Product Design,* Pearson Education, Delhi, 2001.
4. Corrado Poli, *Design for Manufacturing: A Structured Approach,* Butterworth-Heinemann Ltd., 2001

MME 5014: FRACTURE MECHANICS [3 1 0 4]

Fracture mechanics approach to design, brittle and ductile fracture, effect of material properties on fracture. Linear Elastic Fracture Mechanics- fracture modes, fracture criteria, mechanisms of fracture & crack growth, griffith's analysis, energy release rate (G), elastic crack tip fields, stress intensity factor, Crack tip plasticity -Irwin approach, strip yield model, plastic zone shape and size, plane strain fracture toughness. Elastic-Plastic Fracture Mechanics - J-integral, HRR fields, J-controlled crack growth, Crack tip opening displacement. Fracture toughness testing of metals - K_{Ic} test, J_{Ic} measurement, determination of critical CTOD. Fatigue Fracture Mechanics - Fatigue crack growth, crack closure and fatigue threshold, crack growth behavior under variable amplitude loading, effect of overload, prediction of fatigue crack growth and & life of a structural component. Fail safety and damage tolerance - damage tolerance approach of failsafe design, fracture safe design of thick & thin pressure vessels, leak before break, dynamic fracture mechanics, mixed mode fracture initiation and growth, Applications of fracture mechanics to engineering design, FEA of cracks in solids.

References:

1. Anderson T. L., *Fracture Mechanics-Fundamentals and applications*, (3e), CRC Press, London, 2005.
2. Richard W Hertzberg, Richard P Vinci and Jason L Hertzberg, *Deformation and Fracture Mechanics of Engineering Materials,* (5e), John Wiley & Sons, 2012.
3. Broek D., *The Practical Use of Fracture Mechanics*, Springer Netherlands, 1989.
4. Prashant Kumar, *Elements of Fracture Mechanics*, McGraw Hill Education Private Limited, 2013.
5. Norman E Dowling, *Mechanical Behaviour of Materials,* (4e), Prentice Hall, 2012.

MME 5015: MECHANICS OF COMPOSITE MATERIALS [3 1 0 4]

Importance of composite materials, overview, significance and characteristics of composite material, applications and developments, types and classification, Manufacturing of different types of composite materials, quality inspection methods, micro and macro mechanics of fiber reinforced lamina and macro mechanics of composite laminate, testing of composite materials, analysis of laminated composite beams, damage prediction, theories of failures for composite materials.

References:

1. Mallick. P.K., *Fiber Reinforced Composites: Materials, Manufacturing and Design (3e)*, CRC Press, 2007
2. B. D. Agarwal, L.J. Broutman, K. Chandrashekhara, Analysis and performance of fiber composites, Wiely, 2012
3. Robert M. Jones, *Mechanics of Composite Materials (2e)*, Talylor & Francis, 2015
4. Michael W, Hyer, *Stress analysis of fiber Reinforced Composite Materials*, McGraw Hill Publication, 1998.
5. Kishan K. Chawla, Composite materials – Science and Engineering, Springer, 2012
6. F. L. Matthews, R. D. Rawlings, Composite materials: Engineering and Science, CRC Press, 2005

MME 5016: ADVANCED MECHANISMS AND DESIGN [3 1 0 4]

Planar, spherical & spatial mechanisms; Grashoff's law, practical considerations, transmission angle, toggle position, mobility analysis. Synthesis of mechanisms: Type, number & dimensional synthesis; function generation, path generation & body guidance, Chebychev spacing of precision points, two position synthesis of slider crank & crank rocker mechanism, cupler curve synthesis by graphical method, Freudenstein's equation, Bloch synthesis, synthesis of dwell mechanism, intermittent rotary motion, Cognate linkages, Optimum size of cam. Kinematic analysis: Position analysis, vector loop equations for four bar, slider crank, inverted slider crank, geared five bar & six bar linkages; analytical method & auxiliary point method for velocity & acceleration analysis. Path curvature theory: Fixed and moving centrodes, inflection points & inflection circles, Euler Savary equation, graphical constructions, cubic of stationary curvature. Dynamics of mechanisms: Static force analysis with friction, inertia force analysis, combined static & inertia force analysis, shaking force, kinetostatic analysis. Spatial mechanisms and Robotics: Introduction to spatial linkages, special mechanisms, position analysis of RGGR mechanism, Denavit hartenberg parameters, forward & inverse kinematics of robotic manipulators.

References:

1. John J Uicker Jr., Gordon R Pennock and Joseph E Shigley (2003) " Theory of Machines and Mechanisms" Oxford University Press, Delhi
2. Robert L Norton (1999) "Design of Machinery – An Introduction to Synthesis of and Analysis of Mechanisms & Machines" McGraw Hill, New York
3. George N Sandor and Arthur G Erdman (1988) "Advanced Mechanisms Design: Analysis & Synthesis - Volume 2" Prentice Hall of India, Delhi
4. Hamilton H Mabie and Charles F Reinholtz (1987) "Mechanisms and Dynamics of Machinery" John Wiley & Sons, New York

MME 5017: BIO MECHANICS [3 1 0 4]

Overview of biomechanics and related fields, Fundamentals of Newtonian mechanics and weightlessness, Static force applied to the musculoskeletal system, Basic theory of strength of mechanics for hard tissues with infinitesimal strain, Mechanical characteristics of bones and teeth, Fundamentals of viscoelastic theory, Viscoelasticity of soft tissues, Mechanical characteristics of skeletal muscles with active contraction, Fundamentals of continuum mechanics for soft tissues with large strain, Mechanics of cardiovascular system (physiological functions), Mechanics of cardiovascular system (aging and disease), Dynamic characteristics of living tissues with impact, Mechanical tests and finite element analyses for cells and tissues.

References

1. Duane Knudson, Fundamentals of Biomechanics, Springer 2nd ed., 2007
2. Nihat Ozkaya, Fundamentals of Biomechanics: Equilibrium, Motion, and Deformation, Springer India, 2nd ed., 2009.
3. Arthur Chapman, Biomechanical Analysis of Fundamental Human Movements, Human Kinetics Publishers, 2008.
4. Dominique G Poitout , Biomechanics and Biomaterials in orthopedics, Springer Verilog London, 2016.

MME 5018: ROTOR DYNAMICS [3 1 0 4]

Torsional vibration in rotating and reciprocating machinery - Modeling of rotating machinery shafting, transfer matrix analysis for free vibrations,

transient response in torsional vibration, modeling of the reciprocating machine systems, free & forced vibrations, finite element analysis. Bending critical speeds of simple shafts - Whirling of an unbalanced elastic rotor, shafts with several discs, shafts with overhangs. Out of balance response of rotors with rigid supports,

Rotors mounted on Fluid Film bearings. Gyroscopic effects - Gyroscopic of a spinning disc, synchronous whirl of an overhung rotor, nonsynchronous whirl, rotor system with a coupling, finite element method and whirl speed analysis. Stability and whirling of a shaft with dissimilar moments of area. Instability due to fluid film forces and hysteresis, Instability in torsional vibration, Balancing of rigid and flexible rotors.

References:

1. Rao J. S., *Rotor Dynamics*, New Age International (P) Ltd., New Delhi, 1996.
2. Agnieszka Muszynska, Rotordynamics, CRC Taylor & Francis, 2005.
3. Chong-Won Lee, Vibration Analysis of Rotors, Springer Science Business Media, 2012.
4. Krzysztof Czolczynski, Rotordynamics of Gas-Lubricated Journal Bearing Systems, Springer 2012.
5. Friswell M. I., Dynamics of Rotating Machines, Cambridge, 2010.

OPEN ELECTIVES

MME 5053: CORROSION SCIENCE [3 0 0 3]

Definition of corrosion, Importance of corrosion study, Costs of corrosion, Corrosion environments, Corrosion damage, Classification of corrosion, Factors influencing corrosion rate. Uniform corrosion, Galvanic or two metal corrosion, Crevice corrosion, Pitting corrosion, Inter-granular corrosion, Selective leaching, Erosion corrosion, Stress corrosion, Hydrogen damage. Corrosion testing, Purpose, Materials and specimens, Surface preparation, measuring and weighing, Exposure techniques, Duration, Planned interval tests, Aeration, Cleaning specimens after exposure, Standard expressions for Corrosion rate. Corrosion prevention, Materials selection – Metals and alloys, Metal purification, non-metallics, Change of environments – Changing the medium, Use of Inhibitors, Design improvements, Cathodic and anodic protection, Coatings – metallic coating, inorganic coating, organic coating, failure analysis. Corrosion Principles, Electrochemical theory of corrosion, Applications of thermodynamics to corrosion, Free energy, activation energy, Polarization of corrosion reactions, Activation polarization, Concentration polarization, Combined polarization, Pourbaix diagram (E/pH diagram) passivity, Corrosion rate measurements – Tafel extrapolation and Liner polarization techniques.

References:

1. Mars G. Fontana, *Corrosion Engineering*, Third edition Tata McGraw Hill, New Delhi.
2. Zaki Ahmed, Principles of Corrosion Engineering and Corrosion Control, Elsevier Science and Technology Books, 2006.
3. K. R. Trethewey and J. Chamberlain Longman, *Corrosion for students of science and engineering*, Scientific & Technical New York, USA.
4. Schweitzer Philip A, Fundamentals of Corrosion-Mechanisms, Causes and Preventive Methods, CRC Press, Tayler and Francis Group, Boca Raton, 2010.
5. Pierre R. Roberge, *Corrosion Engineering – Principles and practices*, Gulf publishing company.

MME 5054: CREATIVITY FOR PRODUCT DESIGN [3 0 0 3]

Introduction to Product Design - Product Design Process, design by innovation, creativity in design, strength considerations in product design. Tools for design: Information-based tools, Procedure-based tools, Quality Function Deployment, Taguchi technique for robust design, Design for Manufacture, Rapid prototyping; Embodiment design. Creative thinking - The five dimensions of creativity, synthesis, evolution, revolution, re-application and change, creative thinking tools for idea generation and problem solving, convergent and divergent, theory of inventive problem solving. Basic Probability concepts- Basic probability theory, Central Limit Theorem, probability mass function, cumulative distribution function, probability density function. Reliability of Components and Systems- reliability theory, reliability management, history of reliability engineering; reliability allocation, reliability testing.

References:

1. Ulrich Karl T. and Eppinger Steven D., *Product Design and Development*, McGraw Hill International Edition, 1999.
2. Rosenthal Stephen, *Effective Product Design and Development*, Business One Orwin Homewood, 1992.
3. Dieter, *Engineering Design*, McGraw Hill International Edition, 1990.
4. Day Ronald G., *Quality Function Deployment*, Tata McGraw Hill, 1990.
5. Goldenberg and Mazursky, *Creativity in Product Innovation*, Cambridge University Press, 1996.

MME 5055: DESIGN OF EXPERIMENTS [3 0 0 3]

Understanding basic design principles, Working in simple comparative experimental contexts, introduction to R language and its applications in DOE problems, Working with single factors or one-way ANOVA in completely randomized experimental design contexts, Implementing randomized blocks, Latin square designs and extensions of these, Understanding factorial design contexts, Working with two level, 2*k*, designs, Implementing confounding and blocking in 2*k* designs, Working with 2-level fractional factorial designs, Working with 3-level and mixed-level factorials and fractional factorial designs, Simple linear regression models, Understanding and implementing response surface methodologies, Understanding robust parameter designs, Working with random and mixed effects models, Design of computer experiments and the applications in industrial engineering problems.

References:

1. Montgomery, D. C. (2001), *Design and Analysis of Experiments,* John Wiley & Sons. Inc. ISBN: 0-471-31649-0.
2. Dean, A. M. and Voss, D. T. (1999), *Design and Analysis of Experiments (Springer text in Statistics),* Springer Science + Business Media, Inc. ISBN: 0-387-98561-1.
3. Box, G. E. P., Hunter, W. G., and Hunter, J. S. (1978), *Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building,* John Wiley & Sons. Inc. ISBN: 0-471-09315-7.
4. Diamond, W. J. (2001), *Practical Experiment Designs for Engineers and Scientists,* John Wiley & Sons. Inc. ISBN: 0-471-39054-2.
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MME 5056: ENERGY STORAGE SYSTEMS [3 0 0 3]

Need for energy storage, Different modes of energy storage, Pumped hydro storage, Kinetic energy and compressed gas system, Flywheel storage, Compressed air energy storage, Electrical and magnetic energy storage, Capacitors, Electromagnets, Chemical energy storage,

Thermo-chemical, photo-chemical, bio-chemical, electro-chemical, fossil fuels and synthetic fuels, Hydrogen for energy storage, Solar ponds, Electrochemical, Magnetic and Electric Energy Storage Systems: Batteries, Primary, Secondary, Lithium, Solid-state and molten solvent batteries, Lead acid batteries, Nickel Cadmium Batteries, Advanced batteries, Superconducting Magnet Energy Storage (SMES) systems, Capacitor and Batteries, Comparison and application, Super capacitor, Electrochemical Double Layer Capacitor (EDLC),Sensible and Latent Heat Storage: SHS mediums, Stratified storage systems, Rock-bed storage systems, Thermal storage in buildings, Earth storage, Energy storage in aquifers, Heat storage in SHS systems, Aquifers storage, Phase Change Materials (PCMs),Selection criteria of PCMs, Solar thermal LHTES systems, Energy conservation through LHTES systems, LHTES systems in refrigeration and air-conditioning systems, Numerical heat transfer in melting and freezing process, Application of Energy Storage: Food preservation, Waste heat recovery, Solar energy storage, Green house heating, Power plant applications, Drying and heating for process industries.

References:

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2. *IEE Energy Series*, Electro-chemical Power Sources.
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4. P.D.Dunn, *Renewable Energies*. Peter Peregrinus Ltd, London, United Kingdom, First Edition, 1986.
5. Ibrahim Dincer, *Thermal Energy Storage: Systems and Applications*, Wiley Publications, 2010.

MME 5057: INDUSTRIAL SAFETY ENGINEERING [3 0 0 3]

Industrial revolution; Milestones in the safety movement; Accidents & their effects; Cost of accidents; Theories of accident causation - Domino theory, Human factor theory, Accident/incident theory, Epidemiological theory, System theory, Industrial Hazards Ergonomic Hazards; Mechanical Hazards; Fall and impact hazards; Temperature hazards; National Safety Council India (NSCI) and Industrial Safety Acts: Introduction to NSCI; Mission and Vision; Milestones; Management; NSCI safety award schemes; Safety audits; Risk assessment; NSCI safety rating system; Hazard and operational (HAZOP) studies, Industrial Safety Analysis and Management, Preliminary hazard analysis; Detailed hazard analysis; Failure mode and effect analysis (FMEA); Human error analysis (HEA); Environmental Safety: Safety, health and environment.

References:

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MME 5058: LEAN MANUFACTURING [3 0 0 3]

The production system, types, inception &necessity of lean production system, lean revolution in Toyota, basic image of lean production, Principles & characteristics of lean manufacturing, MUDA(waste) and types, lean manufacturing tools and techniques, cellular manufacturing, Continuous improvement, Just-In-Time, production smoothing, Overall equipment efficiency, standardized work and KAIZEN, Standardization of operations, Multi-function workers and job rotation, Improvement activities to reduce work force and increase worker morale foundation for improvements, Shortening of production lead times.

References:

1. Chasel Aquilino, *Productions and Operations Management*, Dreamtech latest edition.
2. Yasuhiro Monden , Toyoto *Production System -An integrated approach to Just in Time, Engineeringaild Management Press* - Institute of Industrial Engineers Norcross Georgia, 1983.
3. James P Womack - Daniel T Jones- and Daniel Roos, *The Machine that changed the World. The Story of Lean Production* - -Harper Perennial - edition published, 1991.
4. James Womack, *Lean Thinking* - ISBN 0743249275, 2003.
5. Richard Schourberger, *Japanese Manufacturing Techniques*. The Nine Hidden Lessons by simplicity - ASQC Press, 1991.

MME 5059: RENEWABLE ENERGY TECHNOLOGY [3 0 0 3]

Solar energy –Production and transfer of solar energy – Sun-Earth angles –Availability and limitations of solar energy – Measuring techniques and estimation of solar radiation. Applications of Solar energy, Energy from biomass – Sources of biomass – Different species – Conversion of biomass into fuels, Aerobic and anaerobic bio-conversion – Properties of biomass, Biogas plants– Design and operation, Wind energy – Principles of wind energy conversion – Site selection considerations –Wind power plant design – Types of wind power conversion systems – Operation, maintenance and economics, fuel cells, fuel cell power plant, Geothermal fields- Hot dry rock, Energy conversion technologies, Ocean thermal energy conversion, Wave and tidal energy: Scope and economics – Introduction to integrated energy systems.

References:

1. J.A. Duffie and W.A. Beckman: Solar Energy Thermal Processes, J. Wiley, 1994.
2. A.A.M. Saigh (Ed): Solar Energy Engineering, Academic Press, 1977
3. F. Kreith and J.F. Kreider: Principles of Solar Engineering, McGraw Hill, 1978
4. G.N. Tiwari: Solar Energy-Fundamentals, Design, Modelling and Applications, Narosa Publishers, 2002
5. H.P. Garg, S.C. Mullick and A.K. Bhargava: Solar Thermal Energy Storage, 1985
6. K.M. Mittal: Non-conventional Energy Systems-Principles, Progress and Prospects, Wheeler Publications, 1997.