(Scheme i.e. applicable for batch 2019 onwards)

DEPARTMENT OF MECHANICAL ENGINEERING, MANIPAL UNIVERSITY JAIPUR

M. Tech. in COMPUTER AIDED ANALYSIS AND DESIGN (CAAD)

Year	FIRST SEMESTER						Relative Weightage					SECOND SEMESTER						Relative Weightage				
	Sub. Code	Subject Name	L	T	P	C	CWS	PRS	MTE	ETE	PRE	Sub. Code	Subject Name	L	T	P	C	CWS	PRS	MTE	ETE	PRE
I	MA6101	Applied Numerical Analysis	3	1	0	4	20	-	40	40	-	ME6201	Fracture Mechanics	3	1	0	4	20	-	40	40	-
	ME6170	Research Methodology	3	0	0	3	20	-	40	40	-	ME6202	Multi Scale Modelling in Design	3	1	0	4	20	-	40	40	-
	ME6101	Finite Element Analysis	3	1	0	4	20	-	40	40	-	ME6203	Advanced Mechanical Vibration	3	1	0	4	20	-	40	40	-
	ME6102	Theory of Elasticity	3	1	0	4	20	-	40	40	-	ME62XX	Program Elective II	3	0	0	3	20	-	40	40	-
	ME6103	Advanced Computer Aided Design	4	0	0	4	20	-	40	40	-	ME62XX	Program Elective III	3	0	0	3	20	-	40	40	-
	ME61XX	Program Elective I	3	0	0	3	20	-	40	40	-	*** ****	Open Elective	3	0	0	3	20	-	40	40	-
	ME6130	Computer Aided Design Lab	0	0	4	2	-	60	-	-	40	ME6230	Finite Element Analysis Lab	0	0	4	2	-	60	-	-	40
												ME6231	CNC Lab	0	0	4	2	-	60	-	-	40
												ME6270	Seminar	0	0	2	1	100	-	-	-	-
			19	3	4	24								18	3	10	26					
	Total Contact Hours (L + T + P)		26									Total Contact Hours (L + T + P) + OE		28+ 3 = 31								
II												THIRD & FOURTH SEMESTER										
	ME7070	Dissertation												0	0	0	25	-	-	25	75	-
														0	0	0	25					
												Total Contact Hours (L + T + P) + OE		0								

(Scheme i.e. applicable for batch 2019 onwards)

Program Elective	**Open Elective**
1. ME6140 Design for Manufacturing 2. ME6141 Biomechanics 3. ME6240 Computer Aided Process Planning 4. ME6241 Optimization Methods in Engineering 5. ME6242 Product Design 6. ME6243 Advanced Mechanism and Design 7. ME6244 Tribology and Bearing Design	1. ME6280 Lean and Agile Manufacturing 2. ME6281 Industrial Safety

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MA6101: APPLIED NUMERICAL ANALYSIS [3 1 0 4]

Mathematical modeling and engineering problem solving: simple mathematical model, conservation laws and engineering. Approximations and round of errors: Accuracy and precision, error definitions, round off errors, truncation errors and Taylor's series. Roots of equations: Bracketing methods, open methods, roots of polynomials applied to engineering problems. Linear algebraic equations: LU decomposition and matrix inversion, special matrices and Gauss Seidel applied to engineering problems. Numerical Differentiation and Integration: Newton Cotes Integration formulas, integration of equations, numerical differentiation applied to engineering problems. Ordinary Differential Equations: RK methods, Boundary value and Eigen value problems. Partial Differential Equations: Finite difference method for elliptic and parabolic equation applied to engineering problems.

References:

1. S.C. Chapra and R.P. Canale, *Numerical Methods for Engineers*, McGraw Hill Publication, 1998.
2. S.S. Sastry, *Numerical Analysis for Engineers*, McGraw Hill Publication, 2002

ME6170: Research Methodology [3 0 0 3]

Mathematical tools for analysis, statistical analysis of data, regression analysis, correlation, concept of best fit and exact fit – Lagrange interpolation, Newton divided difference, least square regression. Design of experiment definition, objective, factorial design, designing engineering experiments, ANOVA, Fractional, Full and Orthogonal Experiments, Taguchi methods for robust design, response surface methodology. Engineering Optimization definition, basics of nonlinear optimization, formulation of optimization problems-examples, Calculus techniques- Lagrange multiplier method – examples, nature inspired optimization techniques i.e. GA, PSO, SA etc., neural network based optimization, optimization using fuzzy systems. Sampling Techniques: basic terms, Importance of sampling in research, essentials of a good sample, sampling error, standard error of the mean (Standard Deviation), Estimation of parameters, accuracy & precision of estimation, sampling procedure, types/methods of sampling, Central limit theorem, sample size determination, confidence interval and Confidence level. Measurement & Scaling Techniques: - types of data: Primary & Secondary, Types of Scales: Ratio, Interval, Ordinal Nominal. Mapping rules, characteristics of a good measurement, sources of error in measurement. Mathematical modeling of Engineering systems Basic concepts of modeling of Engineering systems – Static and dynamic model – Model for prediction and its limitations, system simulation using tools like MATLAB, SPSS, Minitab, COMSOL, Ansys etc.- validation, use of optimization techniques – Genetic Algorithm, Simulated Annealing. Design of Experiments: Basic principles, Study of completely randomized and randomized block design.

References:

1. C R Kothari, *Research Methodology: methods and techniques*, New Age International Publication Ltd
2. J W Creswell, *Research Design*, Sage South Asia Edition
3. D G Montgomery, *Design and analysis of Experiments*, John Willy India Edition
4. Stuart Melville and Wayne guddard, *Research Methodology an introduction for Science & Engineering Students*.
5. Ganesen MJP Publishers, Research Methodology for Engineers, Chennai, 201.

ME6101: FINITE ELEMENT ANALYSIS [3 1 0 4]

Finite Element Basics. Weak Form of PDEs, Finite Element Basis Functions, Direct Stiffness Approach (e.g. spring system), One Dimensional Elements: Bars- uniform, varying and Trusses. Beams, Plane frame. Minimization of functional as solution of governing equations: Variational approach, Potential energy approach, Rayleigh Ritz methods, weak formulations and weighted residual (Galerkin method) methods, Boundary value problems: Rayleigh Ritz and Galerkin approach. 2-D element formulation, Constant Strain Triangle (CST) elements, Lagrange's Element formulations, Isoparametric elements. Errors in FE solutions, Convergence Analysis. Basics of Nonlinear Finite Element Analysis.

References:

1. R.D. Cook, D.S. Malkus, M.E. Plesha and R.J. Witt, *Concepts and Applications of Finite Element Analysis,* (4e), 2002.
2. T.R. Chandrupatla, A.D. Belegundu, *Introduction to Finite Elements in Engineering,* (4e), PHI Learning Private Limited, 2011.
3. J.N. Reddy, *An Introduction to the Finite Element Method*, (3e), 2006.
4. K.J. Bathe, *Finite Element Procedures*, (2e), 2007.
5. T. Belytschko, W.K. Liu, B. Moran and K. Elkhoda, *Nonlinear Finite elements for Continua and Structures,* (2e), Wiley, 2014.

ME6102: THEORY OF ELASTICITY [3 1 0 4]

Definition and Notation: Stress, Stress at a Point, Equilibrium Equations, Principal Stresses, Mohr's Diagram, Maximum Shear Stress, Boundary Conditions. Two Dimensional Problems: Cartesian co-ordinates – Airy's stress functions – Investigation of Airy's Stress function for simple beam problems – Bending of a narrow cantilever beam of rectangular cross section under edge load – method of Fourier analysis – pin ended beam under uniform pressure. General Equations in cylindrical co-ordinates: Thick cylinder under uniform internal and / or external pressure, shrink and force fit, stress concentration. Stresses in an Infinite Plate: Stresses in an infinite plate (with a circular hole) subjected to uniaxial and biaxial loads, stress concentration, stresses in rotating discs and cylinders. Torsion of circular, elliptical and triangular bars: Membrane analogy, torsion of thin open sections and thin tubes. Thermal Stresses: Thermo elastic stress strain relationship, Equations of equilibrium Thermal stresses in thin circular discs and in long circular cylinder, sphere. Uniqueness Theorem: Principle of super position, reciprocal theorem, Saint Venant principle, Contact Stresses.

References:

1. M.H. Sadd. *Elasticity: Theory, Applications and Numerics*, (2e), Academic Press, 2009.
2. S. Timoshenko, J.N. Goodier, *Theory of Elasticity,* (3e), Tata McGraw Hill, 2017.
3. Kassir M. Applied Elasticity and Plasticity. CRC Press, 2017.
4. A.P. Boresi, Elasticity in Engineering Mechanics. Wiley, 2000.

ME6103: ADVANCED COMPUTER AIDED DESIGN [4 0 0 4]

Computer Aided Design: Fundamentals of CAD, Design Process. Transformations- 2D & 3D Transformations. Geometric Modelling: Types of mathematical representation of curves, wire frame models wire frame entities, Curve fitting techniques, parametric representation of synthetic curves, Bezier curves, rational curves; Surface Modelling: Mathematical representation surfaces, Surface model, Surface entities, Parametric representation of surfaces, Tabulated Cylinder; Parametric Topology of Closed Paths, Piecewise flat surfaces, topology of closed curved surfaces, Generalized Concept of boundary, Set theory, Boolean operators, Set-membership Classification, Euler operators, Formal Modelling Criteria. Representation of Synthetic Surfaces: Hermite, Bicubic surface, Bezier surface, B- Spline surface, COONs surface, NURBS, Blending surface, Surface manipulation, Transformations; Geometric Modeling-3D: Solid modelling, Solid Representation, Boundary, Representation (B-rep), Constructive Solid Geometry (CSG).

References:

1. I. Zeid, R. Sivasubramanian, *CAD/CAM Theory and Practice,* Tata McGraw Hill, 2009.
2. D.F. Rogers, J.A. Adams, *Mathematical Elements for Computer Graphics,* (2e), Tata McGraw Hill, 2017.
3. D.F. Rogers, J.A. Adams, *Procedural Elements for Computer Graphics*, (2e), McGraw Hill, 1997.
4. I. Zeid, *Mastering CAD/CAM*, (2e), McGraw Hill, 2006.
5. M.E. Mortension, *Geometric Modeling,* (3e), Industrial Press Inc., 2006.

ME6130: COMPUTER AIDED DESIGN LAB [0 0 4 2]

CAD Introduction, Sketcher, Solid modeling, Extrude, Revolve, Sweep, etc. and Variational sweep, Loft, etc. Surface modeling, Extrude, Sweep, Trim and Mesh of curves, Free form etc. Feature manipulation, Copy, Edit, Pattern, Suppress, History operations etc. Assembly-Constraints, Exploded Views, Interference check, Drafting-Layouts, Standard & Sectional Views, Detailing & Plotting. Exercises in Modeling and drafting of Mechanical Components - Assembly using Parametric and feature based on CAD Package CATIA V6.0 R2013.

Reference:

1. K. Plantberg, *An Introduction of CATIA V6*, (1e), SDC Publication, 2011.

ME6201: FRACTURE MECHANICS [3 1 0 4]

Introduction: Historical perspective, Stress concentration effects of flaws, Fracture Mechanics approach to design, Effect of material properties on fracture, Damage tolerance. Linear Elastic Fracture Mechanics (LEFM): An atomic view of fracture, Stress concentration effect of flaws, Mathematical foundation of LEFM, The Griffith energy balance, The energy release rate, The path independent, J-, L-, and M-integrals, The Westergaard stress function, Stress analysis of cracks, The stress intensity factor, Relationship between K and G, Crack Tip Plasticity, The Irwin's approach, The strip yield model, comparison of plastic zone correction, Plane stress vs Plane strain, K as a failure criterion, Effect of loading mode and specimen dimension. Elastic Plastic Fracture Mechanics (EPFM): Nonlinear Elastic Behaviour and the Energy Release Rate, Crack-Tip Fields in Elastoplastic Materials, Concepts of Crack-Tip Opening Displacement (CTOD), Crack growth resistance curves, J-controlled fracture, Effect of specimen dimension, In-plane dimensions, Three-dimensional effects. Computational Fracture Mechanics: Computational Methods for LEFM, Virtual Crack Extension, Limitations of Numerical Fracture Analysis. Fracture Toughness Testing.

References:

1. T.L. Anderson, *Fracture Mechanics: Fundamentals and Applications,* (4e), CRC Press, 2017.
2. E.E. Gdoutos, *Fracture Mechanics: An Introduction,* (2e), Springer, 2006.

ME6202: MULTISCALE MODELLING IN DESIGN [3 1 0 4]

Length and time scale aspects of materials science problems; connection of these issues with material models (atomic versus continuum); Atomic and continuum scale problems of materials structure and properties; Formalism of atomic scale and continuum scale problems for materials structure and properties. Hierarchical continuum scales in heterogeneous materials. Continuum field equations and constitutive laws; thermodynamics and constitutive theory; thermos mechanics of crystalline materials as an example. Statistical mechanics view and molecular level models. Mechanics and thermo-mechanics of crystalline materials. Homogenization methods in heterogeneous and random media. Contemporary multiscale paradigms: concurrent and hierarchical coupling of materials models at various scales. Theoretical and computational formalism of the quasi-continuum method, coarse-grained molecular dynamics, and bridging scale techniques.

References:

1. E.B. Tadmor, R.E. Miller, *Modeling Materials: Continuum, Atomistic and Multiscale Techniques*, Cambridge University Press, 2011.
2. J.H. Weiner, *Statistical Mechanics of Elasticity,* (2e), Dover Publications, 2017.
3. W.K. Liu, E.G. Karpov and H.S. Park, *Nano Mechanics and Materials:Theory, Multiscale Methods and Applications*, Wiley, 2006.
4. R. Phillips, *Crystals, Defects and Microstructures Modeling Across Scales*, Cambridge University Press, 2001

ME6203: ADVANCED MECHANICAL VIBRATION [3 1 0 4]

Introduction. Transient Vibrations, response of a single degree of freedom system to step and any arbitrary excitation, convolution (Duhamel's) integral. Free, damped and forced vibrations of two degree of freedom systems, Eigen values and Eigen vectors, normal modes and their properties, mode summation method. Multi degree of freedom systems, use of Lagrange's equations. Determination of natural frequency and mode shapes: Rayleigh, Holzer's method. Continuous Systems, Differential equation of motion, solution by the method of separation of variables, frequency parameter, natural frequencies and mode shapes, forced vibration of simply supported beam. Modal analysis of continuous system using finite element method. Vibration Control, Vibration isolation, Vibration absorbers. Non-linear vibration, Examples of Nonlinear Vibration Problems, Exact Methods, Approximate Analytical Methods, Graphical Methods, Stability of Equilibrium States.

References:

1. S.S. Rao, *Mechanical Vibration*, (4e), Pearson Education, 2004.
2. W.T. Thomson, *Theory of Vibrations with Applications,* (5e), Pearson Education, 2008.
3. L. Meirovitch, *Elements of Vibration analysis*, McGraw-Hill, Singapore, 1986.

ME6230: FINITE ELEMENT ANALYSIS LAB [0 0 4 2]

Introduction to formulate the FEA problems. One Dimensional Elements: Bars- uniform, varying and Trusses and Beams Problems. 2D and 3D Problem formulations, Thermal- steady state and transient problems, Mode Analysis, Fluid Structure Interface (FSI) problems. Stress Analysis, Contact Mechanics, Case studies.

References:

1. Y. Nakasone, S. Yoshimoto and T.A. Stolarski, *Engineering Analysis with ANSYS Software,* (2e), Elsevier, Butterworth-Heinemann Imprint, 2018.
2. K.J. Bathe, *Finite Element Procedures*, (2e), 2007.

ME6231: CNC Lab [0 0 4 2]

Project based learning on CNC program simulation for turning and milling. Project based learning on Electrical Discharge Machining (EDM): Practical demonstration and experimentations on drilling, shaper and die manufacturing for effective machinability. Project based learning on Cylindrical and Surface Grinding: Practical demonstration and experimentation on grinding of cylindrical surfaces.

Reference:

1. S.F. Krar, A.R. Gill and P. Smith, *Technology of Machine Tools*, (7e), McGraw Hill Publication, 2014.

Program Elective:

ME6140: DESIGN FOR MANUFACTURING [3 0 0 3]

Introduction to DFMA, steps in DFMA, Introduction to materials, Mechanical properties and material selection, Classification of manufacturing processes. Sand casting: introduction, characteristic, design recommendation. Gating system riser design. Investment casting: design consideration. Die casting: material selection, general design consideration, specific design recommendation. Design for machining: General design rules, dimensional tolerances. Design for turning process, process description, Design for round holes: Introduction, design recommendations, recommended tolerances. Milling: Process description, design recommendations, dimensional tolerances. Grinding: process description, design consideration. Metal Extrusion: Process description, design for metal recommendation for forward and backward extrusion, dimensional accuracy and tolerances. Rolling: Procession description, design recommendation. Welding: introduction to welding, different welding processes, design recommendation, for welding, soldering and brazing.

References:

1. G. Boothroyd, P. Dewhurst and W. Knight, *Product Design for Manufacture and Assembly*, (2e), CRC press, Taylor & Francis, Florida, USA, 2002.
2. O. Molloy, S. Tilley and E.A. Warman, *Design for Manufacturing and assembly*, (1e), Chapman &Hall, London, 1998.
3. G. Boothroyd, *Assembly Automation and Product Design*, (2e), CRC press, Taylor & Francis, 2005.
4. G.E. Dieter, L.C. Schmidt, *Engineering Design*, (4e), McGraw-Hill companies, 2009.

ME6141: BIOMECHANICS [3 0 0 3]

The body nomenclature, planes of reference, ranges of motion, types of tissue, bone, muscle, cartilage, ligament, material properties of these tissues., How to model their elastic behaviour – variableness of elastic properties. Skeletal biomechanics: Composition and structure of bone, biomechanical properties of bone, bone fracture, fracture mechanics, functional adaptation, mechanobiology, structure of collagen, ligament, tendon and cartilage, biomechanical properties of ligament, tendon, and cartilage. Muscle and movements: skeletal muscle morphology and physiology, muscle constitutive modelling, whole muscle mechanics, muscle/bone interactions.

References:

1. D.V. Knudson, *Fundamentals of Biomechanics,* (2e), Springer, 2007.
2. P.M. McGinnis, *Biomechanics of Sport and Exercise,* (3e), Human Kinetics, 2013.
3. D.R. Peterson, J.D. Bronzino, *Biomechanics – Principles & Applications,* (2e), CRC Press, 2008.
4. Y.C. Fung, *Biomechanics: Mechanical Properties of Living Tissues*, (2e), Springer, 1993.

ME6240: COMPUTER AIDED PROCESS PLANNING [3 0 0 3]

Introduction: The Place of Process Planning in the Manufacturing cycle-Process planning and production Planning-Process planning and Concurrent Engineering, CAPP, Group Technology. Part Design Representation: Design Drafting- Dimensioning-Conventional Tolerance- Geometric Tolerance-CAD-input/output devices-Topology – Geometric transformation-Perspective transformation-Data Structure-Geometric modeling for process planning–GT Coding-The OPITZ system-The MICLASS System. Process Engineering and Process Planning: Experience based planning-Decision table and Decision trees-Process capability analysis-Process planning-Variant process planning-Generative approach-Forward and backward planning, Input format, AI. Computer Aided Process Planning Systems: Logical Design of process planning- Implementation considerations-Manufacturing system components, Production Volume, No. of production families – CAM-I, CAPP, MIPLAN, APPAS, AUTOPLAN and PRO, CPPP. An Integrated

Process Planning Systems: Totally integrated process planning systems-An Overview-Modulus structure-Data Structure-Operation-Report Generation, Expert process planning

References:

1. G. Halevi, R.D. Weill, *Principle of process planning- A Logical Approach*, Chapman & Hall, 1995.
2. N. Singh, *Systems Approach to Computer Integrated Design and Manufacturing*, John Wiley & Sons, 1996.
3. P.N. Rao, *Computer Aided Manufacturing*, Tata McGraw Hill Publishing Co., 2000.

ME6241: OPTIMIZATION METHODS IN ENGINEERING [3 0 0 3]

ANOVA & DESIGN OF EXPERIMENTS: Analysis of Variance and its meaning- one-way classification- two-way classification. Basic principles of design of experiments (replication, randomization and local control) - CRD- RBD- LSD. FACTORIAL EXPERIMENTS & TAGUCHI APPROACH: Factorial experiments and their need- and Factorial Experimental Designs without confounding (Theory and Problem only, no derivation expected). Taguchi Approach: Parameter Design, Robust Design. OPTIMIZATION TECHNIQUE BY SEARCH METHOD: Optimal problem formulation -Boundary phase method – Fibonacci search method – Golden section search method – Powell"s conjugate direction method – Conjugate gradient method – Variable-metric method. ALGORITHMIC OPTIMIZATION TECHNIQUE: Kuhn-Trucker conditions – Penalty function method – Frank-Wolfe method – Generalized reduced gradient method – Generalized projection method. OPTIMIZATION TECHNIQUE BY GENETIC ALGORITHM: Genetic algorithms - working principle – difference between GAs and the traditional methods – GAs for constrained optimization – Simulated annealing – Global optimization: using steepest descent method and GA.

References:

1. K. Deb, *Optimization for engineering design*, Prentice Hall of India, 2005.
2. D.C. Montgomery, *Design and Analysis of Experiments*, (8e), John Wiley & Sons, 2012.
3. R.J. Philip, *Taguchi Techniques for quality engineering*, (2e), McGraw Hill, 1995.

ME6242: PRODUCT DESIGN [3 0 0 3]

Introduction to Product Development: Need, Trends, Best practices; Generic product development process and organizations; Product life cycle; Stages of Product development. Conceptual Design: Early design; Customer needs; Requirement Definition and Conceptual design; Quality Function Deployment; Optimization using cost & utility metrics; Trade-off analysis; Design to Life cycle cost; Design for warranties; Competitive Benchmarking. Product Design Evaluation: Detailed design; Design analysis; Prototypes in detailed design; Test and Evaluation; Design review. Design for Manufacture and Assembly: General design principles for manufacturability; Strength and mechanical factors; Mechanism selection; Process capability; Feature & Geometric tolerances; Assembly limits; Datum features. Design for X: Simplification; Commonality and preferred methods; Modularity and scalability; Functional analysis and value engineering; Reliability; Testability; Design for test & inspection; Ergonomics; Maintainability/Serviceability; Safety & product liability; Environment.

References:

1. K.T Ulrich, S.D. Eppinger, *Product Design and Development,* (6e), McGraw-Hill, 2015.
2. K. Otto, K. Wood, *Product Design*, (1e), Pearson Education, 2003.
3. C.A. Phillips, *Human Factors Engineering,* John Wiley and sons, 2000.
4. S.C. Armstrong, *Engineering and product development management – the holistic approach,* Cambridge University press, 2011.
5. C. Poli, *Design for Manufacturing: A structured approach,* (1e), Butterworth-Heinemann, 2001.

ME6243: ADVANCED MECHANISM AND DESIGN [3 0 0 3]

Introduction to kinematics and mechanisms: Motion, The Four-Bar Linkage, Relative Motion, Kinematic Diagrams, Six-Bar Chains, Degrees of Freedom, Analysis versus Synthesis. Analytical Synthesis: The Standard Dyad Form, Number of Prescribed Positions versus Number of Free Choices, Three Prescribed Positions for Motion, Path. And Function Generation, Three-Precision-Point Synthesis Examples, Circle-Point and Center-Point Circles. Mutiloop Mechanisms: Extension of Three-Precision-Point Synthesis to Multiloop Mechanisms, Freudenstein's Equation for Three-Point Function Generation, Loop-Closure-Equation Technique, Order Synthesis: Four-Bar Function Generation, Three-Precision-Point Synthesis: Analytical versus Graphical. Advanced Topics: Motion Generation with Four Prescribed Positions, Solution Procedure for Four Prescribed Positions, Computer Program for Four Prescribed Precision Points, Four Prescribed Motion-Generation Positions: Superposition of Two Three-Precision-Point Cases, Special Cases of Four-Position Synthesis, Motion Generation: Five Positions, Solution Procedure for Five Prescribed Positions, Extensions of Burmester Point Theory: Path Generation, with Prescribed Timing and Function Generation, Further Extension of Burmester Theory, Synthesis of Multiloop Linkages, Applications of Dual-Purpose Multiloop Mechanisms, Kinematic Synthesis of Geared Linkages

References:

1. R.L. Norton, *Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines*, (5e), McGraw Hill, 2011.
2. A.G. Erdman, G.N. Sandor and S. Kota, *Mechanism Design: Analysis and Synthesis,* (4e), Pearson, 2001.
3. K.J. Waldron, G.L. Kinzel, *Kinematic, Dynamics, and Design of Machinery,* (2e), Wiley and Sons, 2004.

ME6244: TRIBOLOGY AND BEARING DESIGN [3 0 0 3]

Introduction to tribology: Newton's Law of viscosity, lubrication principles, classification of lubricants. Hydrodynamic lubrication: Petroff's equation, mechanism of pressure development in an oil film, Reynold's equation. Idealized journal bearing: Load carrying capacity, condition for equilibrium, partial bearings, end leakages. Slider Bearing: Pressure distribution, load carrying capacity, coefficient of friction, frictional resistance in pivoted shoe bearing. Oil flow and thermal equilibrium of journal bearing. Hydrostatic lubrication: Hydrostatic step bearings, load carrying capacity and oil flow. Elasto-hydrodynamic lubrication. Bearing Materials: bearings materials and their properties. Behaviour of tribological components: Selection, friction, wear, surface engineering.

References:

1. G.W. Stachowiak, A.W. Batchelor, *Engineering Tribology*, (3e), Elsevier Inc., 2005.
2. K.C. Ludema, *Friction, Wear, Lubrication: A textbook in Tribology*, CRC Press, 2010.
3. Bharat Bhusan*, Introduction to tribology*, (1e), Wiley, 2002.

Open Elective:

ME6280: LEAN AND AGILE MANUFACTURING [3 0 0 3]

Framework of Toyota Production System, Introduction to Value Stream Mapping, Characteristics of lean value stream. Introduction to Kanban, Production Smoothing, Shortening Production Lead Time, Multifunction Workers, Shortening Setup Time Concepts And Techniques, Organization Structure for Promoting Setup Time Reduction, Standardization of Operations, Yo-i-Don System, One Shot Setup, Determining The Standard Quantity of Work In Progress, Preparing The Standard Operation Sheet. The Agile Production Paradigm, History of Agile Manufacturing, Agile Manufacturing Vs Mass Manufacturing. Agile Practices, Agile practice for product development, Manufacturing agile practices, understanding the value of investing in people, Concept models of Agile Manufacturing, Infusing managerial principles for enabling agility.

References:

1. Y. Monden, *Toyota Production System: An Integrated Approach to Just-In-Time*, CRC Press, 2011.
2. J.M. Gross, K.R. McInnis, *Kanban Made Simple: Demystifying and Applying Toyota's Legendary Manufacturing Process*, AMACOM books, 2003
3. K.W. Dailey, D. Wieckhorst, B. Welch, *The Lean Manufacturing Pocket Handbook*, DW Publishing, 2003.
4. A. Gunasekaran, *Agile Manufacturing 21st Strategy Competitiveness Strategy*, Elsevier Publications, 2001.

ME6281: INDUSTRIAL SAFETY [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:

1. L.G. David, *Occupational Safety and Health for Technologists Engineers and Managers,* (5e), Pearson-Prentice Hall, 2005.
2. F.R. Spellman, N.E. Whiting, *The Handbook of Safety Engineering: Principles and Applications*, The Scarecrow Press Inc., 2010
3. A.K. Gupta, *Industrial Safety and Environment*, Laxmi Publications (P) Ltd., 2006
4. C.R. Asfahi, D.W. Rieske, *Industrial Safety and Health Management,* (7e), Pearson, 2018.