CURRICULUM AND SYLLABI

M.Tech.

in

MACHINE DESIGN

(With effect from Academic Year 2018-2019)

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
CALICUT - 673601

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Curriculum of M. Tech. in Machine Design

Programme Educational Objectives

PEO1: To train students with in-depth and advanced knowledge to become highly- skilled professionals in machine design and allied fields like solid mechanics and dynamics, capable of analysing and solving complex engineering problems.

PEO2: To enable graduates to carry out innovative and independent research work in academia/industry to enhance the solid mechanics and dynamics knowledge base, and to disseminate the knowledge.

PEO3: To prepare the students to exhibit a high level of professionalism, integrity, social responsibility and life-long independent learning ability.

Programme Outcomes

PO1: An ability to independently carry out research/investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the Machine Design programme. The mastery should be at a level higher than the requirements in the appropriate bachelor programme.

PO4: Ability to conduct research, do self-learning and share in-depth knowledge in the areas of solid mechanics, dynamics and machine design.

PO5: Ability to critically analyse complex problems in the field of machine design and arrive at optimal solutions.

PO6: Ability to use modern computer/ software tools to model, analyse and design mechanical systems.

Curriculum of M. Tech. in Machine Design

First Semester					
Code	**Title of Course**	**L**	**T**	**P**	**C**
MA6001D	Mathematical Methods	3	0	-	3
ME6601D	Advanced Mechanics of Solids	3	0	-	3
ME6602D	Theory of Vibrations	3	0	-	3
	Elective 1	3	0	-	3
	Elective 2	3	0	-	3
ME6691D	Design Engineering Laboratory	-	0	3	2
	Total	**15**	**0**	**3**	**17**

Second Semester					
Code	**Title of Course**	**L**	**T**	**P**	**C**
ME6611D	Theory of Mechanisms	3	0	-	3
ME6612D	Finite Element Method and Applications	3	0	-	3
ME6613D	Advanced Methods in Engineering Design	3	0	-	3
	Elective 3	3	0	-	3
	Elective 4	3	0	-	3
ME6692D	CAD Laboratory	-	0	3	2
ME6693D	Seminar/Mini Project	-	0	2	1
	Total	**15**	**0**	**5**	**18**

Third Semester					
Code	**Title of Course**	**L**	**T**	**P**	**C**
ME7694D	Project (Part-I)	0	0	20	12
	Total	**0**	**0**	**20**	**12**

Fourth Semester					
Code	**Title of Course**	**L**	**T**	**P**	**C**
ME7695D	Project (Part-II)	0	0	20	13
	Total	**0**	**0**	**20**	**13**

L: Lecture, T: Tutorial: P, Practical, S: Seminar, C: Credit

Total Credits: 60

Notes

1. A minimum of 60 credits (Maximum credits permitted 62) have to be earned for the award of M. Tech. degree in this programme.
2. Students may audit the course on '*Communicative English*' in the first or second semester of the programme and this course shall not be indicated in the grade card.
3. For elective courses, students may choose any PG level course offered in the Institute with the approval from the Programme Coordinator.
4. It is desirable for students to undergo *Two Months* Industrial Training/Internship during summer vacation.
5. Students are permitted to audit course/s in the Third and Fourth Semesters of the programme. Only a maximum of two audited courses for which a minimum pass (P) grade secured shall be recorded in the grade card.

Credit distribution

Curricular composition	Credits
Theory courses	30
Laboratory courses	4
Seminar	1
Projectworks	25
Total credits	**60**

List of Elective Courses

Stream-specific elective courses			
Sl. No.	**Code**	**Title of Course**	**C**
1	ME6621D	Rigid Body Mechanics	3
2	ME6622D	Behaviour and Selection of Materials	3
3	ME6623D	Industrial Tribology	3
4	ME6624D	Design of Electro-Mechanical Systems	3
5	ME6625D	Nonlinear Dynamics	3
6	ME6626D	Product Design	3
7	ME6627D	Design of Pressure Vessels and Piping	3
8	ME6628D	Theory of Plasticity: Fundamentals and Computational Methods	3
9	ME6629D	Continuum Mechanics	3
10	ME6630D	Experimental Stress Analysis	3
11	ME6631D	Fracture Mechanics and Fatigue	3
12	ME6632D	Robotics	3
13	ME6633D	Mechatronics Systems and Fluid Power Automation	3
14	ME6634D	Rotor Dynamics	3
15	ME6635D	Analytical and Nonlinear Dynamics	3
16	ME6636D	Computer Graphics	3

Other suggested elective courses			
Sl. No.	**Code**	**Title of Course**	**C**
1	ME6328D	Design of Experiments	3
2	ME6323D	Six Sigma	3
3	ME6305D	Industrial Automation and Robotics	3
4	ME6321D	Mechatronics Systems	3
5	ME6332D	Design for Manufacturability and Assembly	3
6	ME6330D	Vibration and Noise in Machine Tools and Machining	3

DEPARTMENT OF MECHANICAL ENGINEERING

Detailed Syllabi for the M. Tech. Programme in

MACHINE DESIGN

MA6001D MATHEMATICAL METHODS FOR ENGINEERS

Pre-requisites: Nil

Total hours: 39

L	T	P	C
3	0	0	3

Module 1: (10 hours)
Linear Algebra: vector spaces, subspaces, basis, dimension, inner product spaces, Gram-Schmidtprocess, linear transformations, range and kernel, isomorphism, matrix of transformations and change ofbasis.
Module 2: (9 hours)
Series Solutions of ODE and Sturm-Liouville Theory: power series solutions about ordinary point, Legendre equation and Legendre polynomials, solutions about singular points; the method of Frobenius, Bessel equation and Bessel functions; Sturm-Liouville problem and generalized Fourier series.
Module 3: (10 hours)
Partial Differential Equations:first order PDEs, linear equations, Lagrange method, Cauchy method, Charpits method, Jacobi method; second order PDEs: classification, method of separation of variables, formulation and solution of wave equation, heat equation and Laplace equation.
Module 4: (10 hours)
Tensor Calculus:spaces of *n*-dimensions, coordinate transformations, covariant, contravariant and mixed tensors, fundamental operation with tensors, quotient law, the line element and metric tensor, conjugate tensor, Christoffel’s symbols, covariant derivative.

References:

1. D. C. Lay, *Linear Algebra and its Applications*. Addison Wesley,2003.
2. F. G. Florey, *Elementary Linear Algebra with Application*. Prentice Englewood, 1979.
3. W. W. Bell, *Special Functions for Scientists and Engineers*. Dover Publications,2004.
4. I.Sneddon, *Elements of Partial Differential Equations*. McGraw Hill International, 1985.
5. B. Spain, *Tensor Calculus*, Oliver and Boyd,1965.
6. K. S. Rao, *Introduction to Partial Differential Equations*, 3rd ed. Prentice-Hall, 2010.
7. S. L. Ross, *Differential Equations*, 3rd ed. John Wiley & Sons, 2004.
8. L.A.Pipes and L.R. Harwill, *Applied Mathematics for Engineers and Physicists*. McGraw Hill, 1971.
9. M.A. Akivis and V.V. Goldberg, *An Introduction to Linear Algebra and Tensors*. Dover Publications,1997.
10. P. K.Nayak, Text book of Tensor Calculus and Differential Geometry.PHI Learning, 2012.

ME6601D ADVANCED MECHANICS OF SOLIDS

Pre-requisites:Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (13 hours)
Introduction to three-dimensional elasticity,analysis of stress: Cauchy's formula, stress tensor, principal stress, hydrostatic and deviatoric stresses, stress transformation, octahedral stresses, Mohr's circle; analysis of strain: strain tensor, principal strains, strain tensor, analogy with stress tensor, strain energy, governing equations: equations of equilibrium, kinematic relations, constitutive relations, Lame's constants, compatibility conditions, boundary conditions, Navier's equations; equations in polar coordinates.

Module 2:(13 hours)
Simplification to 2D problems: plane stress and plane strain problems, axisymmetric problems, thick cylinder, rotating disc, curved beams, shrink fits, case studies using software.
Energy methods: energy theorems, principle of virtual work, minimum potential energy principle; use of energy theories for calculating deflections and stresses.
Special problems in bending: unsymmetric bending, shear centre.
Solutions using polynomials, Airy's stress function, stress concentration problems.
Case studies using software.

Module 3: (13 Hours)
Torsion of noncircular sections: Saint Venant's semi inverse method, Prandtl's stress function approach, linear elastic solution of various standard noncircular sections, membrane analogy, narrow rectangular cross sections, thin-walled members.
Introduction to plasticity: theory of plasticity, theories of failure and yield criteria for metals, plastic stress-strain relationships.

References:
1. S. TimoshenkoandJ. N. Goodier, *Theory of Elasticity*. McGraw Hill, 1970.
2. L. S.Srinath, Advanced Mechanics of Solids, 3rd ed.Tata McGraw Hill, 2009.
3. A. J. Durelli, E. A. Philips and C. H. Tsao, *Introduction to the Theoretical and Experimental Analysis of Stress and Strain*, McGraw Hill, 1958.
4. Y. C. Fung, *Foundations of Solid Mechanics*, 2nd ed. Prentice Hall, 1965.
5. A. P. Boresi andR. J. Schmidt, *Advanced Mechanics of Materials*, 6th ed. Wiley, 2002.
6. K.B.M. Nambudiripad, *Advanced Mechanics of Solids – A Gentle Introduction*. Narosa, 2017.
7. R. T. Fenner, *Engineering Elasticity: Applications of Numerical and Analytical Techniques*. Ellis Hodwood, 1986.
8. W. Johnson and P. B.Mellor, *Engineering Plasticity*. Van Nostrand Reinhold, 1983.

ME6602D THEORY OF VIBRATIONS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Module 1: (14 hours)
Review of mechanical vibration; single degree of freedom systems: free and forced vibrations, viscous and Coulomb damping, response to harmonic excitation, rotating unbalance, support excitation, transmissibility and vibration isolation, vibration measuring instruments; response to periodic and arbitrary excitation.

Module 2: (12 hours)
Critical speed of rotors, energy method, Rayleigh's method, equivalent viscous damping, Laplace transform and Fourier transform methods.
Two-DOF systems: free vibration, matrix formulation, beat phenomenon, forced vibration, principle of vibration absorbers.
Multi-DOF Systems: matrix formulation, stiffness and flexibility influence coefficients, eigen value problem, normal modes and their properties.

Module 3: (13 hours)
Matrix iteration technique for eigen values and eigen vectors, free and forced vibration by model analysis.
Applications of Lagrange's equation in vibration problems.
Continuous systems: transverse vibration of strings, bending vibration of beams, axial vibration of bars, torsional vibration of shafts, free and forced vibrations.
Classical methods of Rayleigh, Dunkerly and Holzer; computational exercises.

References:
1. W.T. Thomson, *Theory of Vibration with Applications*. Prentice hall of India, 2003.
2. L. Meirovitch, *Elements of Vibration Analysis*. McGraw-Hill, 1986.
3. S. S. Rao, *Mechanical Vibrations*, 4th ed. Pearson, 2004.
4. J. P. Den Hartog, *Mechanical Vibrations*. McGraw-Hill, 1956.

ME6691D DESIGN ENGINEERING LABORATORY

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total hours: 39

Tribology: measurement of friction and wear using pin-on-disc tribometer and four-ball wear tester; study and demonstration of Scanning Electron Microscope (SEM), Atomic Force Microscope (AFM), Machinery Fault Simulator, High Frequency Reciprocating Rig (HFRR) and Rheometer.
Vibration: study of simple pendulum, torsional vibration and determination of radius of gyration of a given pendulum, bi-filar suspension and tri-filar suspension, damped and undamped vibration.
Metrology: calibration of transducers, strain gauge load cell, LVDT.
Robotics: studies on programmable logic controller (PLC), familiarization with pneumatic hardware and circuits, exercises on robots.

List of Experiments:

1. Study of pendulum: determination of radius of gyration, bi-filar and tri-filar suspension.
2. Friction and wear test using four-ball tester.
3. Friction and wear test using pin-on-disc tribometer.
4. Torsional vibration of a single rotor system: forced undamped vibration, free and forced damped vibration; torsional vibration of a two-rotor system.
5. Measurements using strain gauges.
6. Study and demonstration of SEM and AFM.
7. Studies on machine fault simulator.
8. Dynamic viscosity measurement using Rheometer.
9. Studies on HFRR.
10. Demonstration of pneumatic circuit design and testing using hardware; familiarization with PLC: demonstration of ladder Logic Diagrams and programming exercises.
11. Measurements of accuracy and repeatability of robots.

References:

1. J. W. Dally and W. E. Riley, *Experimental Stress Analysis*, 3rd ed. McGraw-Hill, 1991.
2. L. S. Srinath, M. R. Raghavan, K. Lingaiah, G. Garghesha, B. Pant, and K. Ramachandra, *Experimental Stress Analysis*. Tata McGraw-Hill, 1984.
3. M.Qiu, L. Chen, Y. Li,and J. Yan, *Bearing Tribology: Principles and Applications*. Springer, 2016.
4. T. Mang, K.Bobzin, and T. Bartels, *Industrial Tribology: Tribosystems, Friction, Wear and Surface Engineering, Lubrication*. Wiley-VCH, 2010.
5. W.T. Thomson, *Theory of Vibration with Applications*. Prentice Hall of India, 2003.
6. S. B.Niku,*Introduction to Robotics, Analysis, Systems and applications*, 2nd ed. Prentice Hall of India, 2010.
7. D. Shetty and R. A.Kolk, *Mechatronics System Design*, 2nd ed. Thomson Learning, 2001.

ME6611D THEORY OF MECHANISMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1:(14 Hours)
Introduction to mechanisms and their applications; mobility, complex mechanisms, analysis of complex mechanisms: auxiliary point method, method of normal components, Goodman's indirect method.
Synthesis of planar mechanisms: graphical synthesis of planar mechanisms for rigid body guidance, path generation and function generation.

Module 2:(12 Hours)
Analytical synthesis of planar mechanisms: Freudenstein's equation.
Introduction to path curvature theory: pole, centrode, inflection circle, Euler-Savary equation, cubic of stationary curvature.
Spatial mechanisms: spherical and spatial linkages, degree of freedom, displacement equation; synthesis of a spatial cam; case studies in mechanisms.

Module 3: (13 Hours)
Introduction to compliant mechanisms; flexibility and deflection; pseudo-rigid body model, variety of models such as small length flexural pivots, fixed-pinned beam, fixed-guided flexible segment; methods of modeling pin joints, Q-joints, torsional hinge; examples of modeling of compliant mechanisms.

References:

1. A.K. Mallik, A. Ghosh, and G.Dittrich, *Kinematic Analysis and Synthesis of Mechanisms*. CRC Press, 1994.
2. G. N.Sandor, A. G. Erdman, *Advanced Mechanism Design: Analysis and Synthesis*, Vol.2. Prentice Hall, 1984.
3. A.Ghoshand A. K.Mallik, *Theory of Mechanisms and Machines*, 3rd ed. Affiliated East West Press, 2014.
4. L. L.Howell, *Compliant Mechanisms*, John Wiley & Sons, 2001.
5. J. J. Uicker, G. R.Pennock, and J. E Shigley, *Theory of Machines and Mechanisms*, 3rd ed.Oxford University Press, 2009.
6. R. L. Norton, *Design of Machinery*, 3rded.Tata McGraw-Hill, 2005.

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ME6612D FINITE ELEMENT METHOD AND APPLICATIONS

Pre-requisites: ME6601D Advanced Mechanics of Solids / Equivalent

L	T	P	C
3	0	0	3

Total Hours: 39

Module 1: (12 hours)
Introduction: discrete systems, assembly process, boundary conditions and solution, continuum systems; variational calculus: basics, Euler-Lagrange equation, classical applications like shortest distance problem, Brachistochrone problem, etc.; general principles in elasticity: differential and integral statements, principles of minimum potential energy and virtual work; finite element formulation: Galerkin weighted residual method, variational formulation using principles of minimum potential energy and virtual work, handling boundary conditions: essential and natural boundary conditions.

Module 2: (14 hours)
One-dimensional finite element analysis: shape functions, finite element formulation, assembly and boundary conditions, continuity requirements and order of shape functions.
Two-dimensional finite element analysis: introduction; scalar-field problems: heat transfer, torsion and potential flow problems, shape functions for triangular elements, formulation, assembly and solution; vector-field problems: stress analysis problem, rectangular elements, Lagrangian interpolation polynomials, isoparametric formulation and higher order elements, formulation, assembly and solution, introduction to three-dimensional problems.

Module 3: (13 hours)
Computational aspects: mesh generation; element shape parameters; node numbering; storage and solution schemes; finite element analysis using commercial software.
Transient analysis: finite differences and time-stepping schemes, accuracy and stability.
Nonlinear analysis: material, geometric and boundary nonlinearities, fixed-point iteration, Newton-Raphson and modified Newton-Raphson techniques, convergence and tolerance.

References:

1. J. N. Reddy, *An Introduction to the Finite Element Method*, 3rd ed. McGraw Hill Education, 2017.
2. O. C. Zienkiewicz, R. L. Taylor, and J. Z. Zhu, *The Finite Element Method: Its Basis & Fundamentals*, 7th ed. Butterworth-Heinemann, 2013.
3. R. D. Cook, D. S. Malkus, M. E. Plesha, and R. J. Witt, *Concepts and Applications of Finite Element Analysis*, 4th ed. Wiley, 2001.
4. K. J. Bathe, *Finite Element Procedures*. Prentice-Hall of India, 1996.

ME6613D ADVANCED METHODS IN ENGINEERING DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Module 1: (15 hours)
Product Design: concepts of product design, modeling and simulation, material selection; design for manufacturability: design recommendations for products made by various manufacturing processes such as turning, milling, welding, casting, forging etc.

Module 2: (12 hours)
Reliability: definition, fundamentals of reliability, factor of safety and reliability, reliability tests, reliability techniques, availability and maintainability concepts.

Module 3: (12 hours)
Failure Analysis: sources of failure, methodology of failure analysis, fractography, metallography, polymer failures, failure of ceramics and glass, failure analysis case studies.

References:
1. K. T. Ulrich and S. D. Eppinger, *Product Design and Development*, McGraw-Hill, 2004.
2. B. W. Niebel and A. B. Draper, *Product Design and Process Engineering*, McGraw Hill, 1974.
3. G. E. Dieter, *Engineering Design*, 2nded. McGraw Hill, 1991.
4. S.S.Rao, *Reliability Based Design*, McGraw Hill, 1992.
5. L.S.Srinath, *Concepts in Reliability Engineering*, Affiliated East West Press, 2003.
6. J. E.Shigley, C. R.Mischke, and R. G. Budynas, *Mechanical Engineering Design*, 7th ed.McGraw Hill, 2003.
7. ASM Handbook, Vol. 11, *Failure Analysis and Prevention*, ASM Publications, 2002.

ME6692D CAD LABORATORY

Pre-requisites: Nil

Total Hours: 39

L	T	P	C
0	0	3	2

Computer Aided Design: demonstration of part modeling, assembly and mechanism modeling; finite element analysis: static structural and coupled thermal stress analyses, exercise on geometry importing and meshing, modal analysis, nonlinear analysis: geometric, material and boundary nonlinearities, transient structural and impact analyses; multi-body dynamics analysis: kinematic analysis of four-bar mechanism, dynamic analysis of slider-crank chain.

List of Exercises:

Computer Aided Design:
1. Demonstration of part modeling, assembly and mechanism modeling.

Finite Element Analysis:
2. Static structural analysis.
3. Coupled thermal stress analysis.
4. Meshing of a complicated 3-D model imported from modeling software.
5. Modal analysis to obtain natural frequencies.
6. Buckling analysis.
7. Elasto-plastic analysis.
8. Contact analysis.
9. Transient structural analysis.
10. Impact analysis (involving contact, plastic deformation and dynamics).

Multi-body Dynamics Analysis:
11. Kinematic analysis of four-bar mechanism.
12. Dynamic analysis of slider-crank chain.

References:

1. E. P. Popov, *Engineering Mechanics of Solids*, 2nd ed. Prentice Hall of India, 2000.
2. S. P. Timoshenko and J. N. Goodier, *Theory of Elasticity*. McGraw Hill International, 1970.
3. M. H. Sadd, *Elasticity: Theory, Applications and Numerics*, 3rd ed. Academic Press, 2014.
4. M. K. Thompson and J. M. Thompson, *ANSYS Mechanical APDL for Finite Element Analysis*. Butterworth-Heinemann, 2017.
5. K. L. Johnson, *Contact Mechanics*. Cambridge University Press, 1985.
6. O. C. Zienkiewicz, R. L. Taylor, and J. Z. Zhu, *The Finite Element Method: Its Basis and Fundamentals*, 7th ed. Butterworth-Heinemann, 2013.
7. S. S. Rattan, *Theory of Machines*. Tata McGraw-Hill, 2014.
8. ANSYS Mechanical APDL Documentation.
9. MD ADAMS Product Documentation.

ME6693D SEMINAR/MINI PROJECT

L	T	P	C
0	0	2	1

Total hours: 26

Students are free to select either Seminar or Mini Project after consulting with Programme Coordinator/Course Faculty.

SEMINAR

Each student shall prepare a seminar paper on any topic of interest related to the core/elective courses undergone in the first semester of the M. Tech. programme. He/she shall get the paper approved by the Programme Coordinator/Faculty Members in the concerned area of specialization and shall present it in the class in the presence of the Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student's paper, presentation and his/her participation in the seminar.

MINI PROJECT

Students can select a research / product design problem pertaining to the area of specialization of the M. Tech. programme by consulting a faculty in the department. The student has to identify an appropriate methodology and solve the problem. The student shall prepare submit a report. The mini project will be evaluated by the faculty in-charge of the mini project.

ME7694D PROJECT (PART-I)

L	T	P	C
0	0	20	12

Studentsare encouraged to identify the area of the project work and conduct the literature review during the second semester itself. The project work starts in the third semester. The topic shall be research and development oriented. The project work can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project work in an industry or in other organizations have to fulfill the requirements as specified in the "Ordinances and Regulations for M. Tech."The student is expected to complete the research problem definition, formulation and preliminary work (pilot study) in the third semester. There shall be evaluations of the project work during and at the end of the third semester by a committee constituted by the department.

ME7695D PROJECT (PART-II)

L	T	P	C
0	0	20	13

The project work started in the third semester will be extended to the end of the fourth semester. There shall be evaluations of the project work by a committee constituted by the department during the fourth semester. The student shall submit the thesis based on the recommendation of the departmental evaluation committee. There shall be viva-voce examination conducted by an evaluation committee with an external examiner.

Elective Courses:

ME6621D RIGID BODY MECHANICS

Pre-requisites: Nil

Total Hours: 39

L	T	P	C
3	0	0	3

Module 1 (14 hours)
Fundamentals: introduction, idealizations of mechanics, equality and equivalence of vectors, laws of mechanics, moment of a force about a point and an axis, couple and couple moment, resultant of a force system, free body diagram, equations of equilibrium, applications of equations of equilibrium.
Particle kinematics and dynamics:velocity and acceleration calculations in rectangular and cylindrical coordinates, Newton's law for rectangular and cylindrical coordinates, energy and momentum methods for a particle.

Module 2 (12 hours)
Rigid body kinematics:translation and rotation of rigid bodies, Chasles' theorem, derivative of a vector fixed in a moving reference, applications of the fixed-vector concept, general relationship between time derivatives of a vector for different references, relationship between velocities of a particle for different references, acceleration of a particle for different references.
Moments and products of inertia: formal definition of inertia quantities, translation of coordinate axes, transformation properties of inertia terms, inertia ellipsoid and principal moments of inertia.

Module 3 (13 hours)
Kinetics of plane motion of rigid bodies: moment-of-momentum equations: pure rotation of a body of revolution, body with two orthogonal planes of symmetry and slablike bodies, rolling of slablike bodies, General plane motion of a slablike body, pure rotation of an arbitrary rigid body.
Energy and impulse-momentum methods for rigid bodies: kinetic energy of a rigid body, work-energy relations, angular momentum of a rigid body, impulse-momentum equations.
Dynamics of general rigid-body motion: Euler's equations of motion and applications, necessary and sufficient conditions for equilibrium of rigid body, three-dimensional motion about a fixed point: Euler angles, equations of motion using Euler angles.

References:

1. I. H. Shames, *Engineering Mechanics: Statics and Dynamics*, 4thed. Prentice Hall, 1996.
2. F. P. Beer and E. R. Johnston, *Vector Mechanics for Engineers*. McGraw-Hill, 2000.
3. J. L. Meriam and L. G. Kraige, *Engineering Mechanics – Dynamics*. John Wiley & Sons, 2002.

ME6622D BEHAVIOUR AND SELECTION OF MATERIALS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Module 1: (14 hours)

Fundamentals: general introduction; evolution of engineering materials; the design process; materials classification: families of engineering materials and their properties; hybrids and composite materials – classification and properties; material property charts; materials selection basics, price and availability of materials.

Materials Selection Based on Properties-1:

Elastic properties: atomic structure and bonding; physical basis of elastic properties; case studies in modulus-limited design.

Module 2: (12 hours)

Materials Selection Based on Properties-2:

Plastic behavior: yield strength, tensile strength and ductility; dislocations and yielding; strengthening methods; plasticity of polycrystals; continuum aspects of plastic flow; case studies in yield-limited design.

Vibration and acoustics considerations in materials selection.

Materials selection based on fracture toughness, fatigue failure, friction and wear.

Module 3: (13 hours)

Materials Selection Based on Properties-3: Thermal properties, creep and diffusion, case studies in design based on thermal properties, materials selection based on chemical properties: oxidation and corrosion, electrical, magnetic and optical properties of materials.

Miscellaneous Topics: Multi-objective optimization; shape, feel and appearance of materials; process selection; materials and environment; final case study.

References:

1. M. F. Ashby, *Materials Selection in Mechanical Design*, 4th ed. Butterworth-Heinemann, 2011.
2. M. F. Ashby, H. Shercliff, and D. Cebon, *Materials: Engineering, Science, Processing and Design*, 3rd ed. Butterworth-Heinemann, 2014.
3. M. F. Ashby and D. R. H. Jones, *Engineering Materials* – 1, 4th ed. Butterworth-Heinemann, 2011.
4. D. Tabor, *Gases, Liquids and Solids, and other States of Matter*, 3rd ed. Cambridge University Press, 1969.
5. G. E. Dieter, *Mechanical Metallurgy*, SI Metric ed. McGraw-Hill, 1988.
6. G. E. Dieter and L. C. Schmidt, *Engineering Design*, 5th ed. McGraw-Hill, 2012.

ME6623D INDUSTRIAL TRIBOLOGY

Pre-requisites: Advanced Mechanics of Solids

Total Hours: 39

L	T	P	C
3	0	0	3

Module 1: (15 hours)
Introduction: basic equations; derivation of Reynolds equation; energy equation; idealized hydrodynamic bearings; mechanism of pressure development; plane slider bearings; idealized journal bearings; infinitely long and short bearings.
Finite bearings: performance characteristics, numerical solution, hydrodynamic instability.

Module 2: (13 hours)
Design of journal bearings; analysis of externally pressurized and gas lubricated bearings.
Costs of wear; surface topography; mechanics of contact.
Theories of friction: Friction of metals and non-metals; stick-slip; rolling friction; temperature of sliding surfaces.

Module 3: (11 hours)
Wear of metals: adhesive wear; abrasive wear; corrosion and corrosion wear; erosion; surface fatigue and impact wear; wear of elastomers; wear of ceramics and composite materials; measurement of friction and wear, Introduction to nanotribology.

References:
1. B. C. Majumdar, *Introduction to Tribology*, 4th ed. A.H. Wheeler, 1978.
2. O. Pinkus and B. Sternlicht, *Theory of hydrodynamic lubrication*. McGraw-Hill, 1961.
3. D. F. Moore, *Principle and Application of Tribology*. Pergamon Press, 1975.
4. E. Rabinowicz, *Friction and Wear of Materials*, 2nd ed. John Wiley & Sons, 1995.
5. K. L. Johnson, *Contact Mechanics*. Cambridge University Press, 1985.
6. T. R. Thomas, *Rough Surfaces*, 2nd ed. Imperial College Press, 1999.

ME6624DDESIGN OF ELECTRO-MECHANICAL SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module1:(13 hours)
Introduction to Electro-Mechanical Systems (EMS): mechatronics Vs EMS, elements of EMS, physical systems and their mathematical models: mathematical models of mechanical, electrical, hydraulic and pneumatic elements and systems; transfer function approach, block diagram reduction, state space representation.

Module 2:(12 hours)
Sensors and Actuators: selection of actuators and sensors, position, force/torque, temperature vision sensors and sensors for micro level applications; permanent magnet, stepper, servo and ac motors, mechanical actuators, electro-mechanical actuators, actuators for micro level applications: piezoelectric, SMA and magnetostrictive actuators.

Module 3:(14 hours)
Drives and basic solid-state components and devices: various components and elements of electromechanical energy conversion, starting, inversion and control of electrical drives, motor drivers (h-bridge and PWM control), basics of digital signal processing data acquisition, types and applications op-amp circuits and filters.
Introduction to control of electromechanical systems and PID control laws: elements of telemetry and remote control of mechatronic systems, design and implementation of control strategies for mechanical system;design of proportional, integral, derivative and PID controllers, analog and digital PID control laws and applications.

References:

1. W. Bolton, *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*,2nd ed. Addison Wesley Longman Limited, 1999.
2. D. Necsulescu, *Mechatronics***.** Pearson Education, 2002.
3. R. C. Drof and R. H. Bishop, *Modern Control Systems***.**Addison Wesley, 1998.
4. K. Kant,*Computer Based Industrial Control*.Prentice Hall of India, 1999.
5. HMT Limited,*Mechatronics***.**Tata McGraw-Hill, 1998.
6. H.Taub and D. Schilling, *Digital Integrated Electronics*. McGraw Hill International Edition, 1977.
7. S.E. Lyshevski, *Electromechanical Systems and Devices.*CRC Press, 2008.
8. C.W. de Silva, Mechatronics*: an Integrated Approach*. CRC Press, 2004.

ME6625D NONLINEAR DYNAMICS

Pre-requisites: Nil

Total hours: 39

L	T	P	C
3	0	0	3

Module 1: (13 hours)
Introduction to dynamical systems: discrete time and continuous time systems: autonomous and nonautonomous systems, phase space and flows, attracting sets, concepts of stability, fixed point, limit cycle, bifurcation: bifurcation of maps; chaotic solutions of maps.

Module 2: (13 hours)
Types of bifurcation; chaotic solutions of continuous systems, period doubling and intermittency mechanisms.
Quasiperiodic solutions: Poincare' maps, circle map.
Fractals and dynamical systems: fractal dimension, measures of fractal dimension.

Module 3: (13 hours)
Tools to identify and analyze motions: Fourier spectra, Poincare' sections and maps, Lyapunov exponents.
Computational methods: numerical integration, cell mapping, harmonic balance, shooting method, parametric continuation.
Applications to mechanical systems: gear with backlash, clutch, springs, bearings etc.

References:
1. A. H. Nayfeh and B.Balachandran, *Applied Nonlinear Dynamics*. Wiley VCH, 1995.
2. J. M. T.Thomson and H.B. Stewart, *Nonlinear Dynamics and Chaos*, 2nd ed. Wiley-Blackwell, 2001.
3. F. C.Moon, *Chaotic and Fractal Dynamics*, 2nd ed. Wiley VCH, 1992.
4. S.H.Strogatz, *Nonlinear Dynamics and Chaos*.Levant Books, 2007.
5. D.W.Jordan and P. Smith, *Nonlinear Ordinary Differential Equations*, 4thed.Oxford University Press,2007.

ME6626D PRODUCT DESIGN

Pre-requisites: Nil

Total hours: 39

L	T	P	C
3	0	0	3

Module 1: (12 hours)
Introduction, development processes and organizations, opportunity identification, product planning, identifying customer needs, product specifications.

Module 2: (14 hours)
Concept generation, concept selection, concept testing, product architecture, industrial design, design for environment, design for manufacturing, prototyping, robust design.

Module 3: (13 hours)
Patents and intellectual property, service design, design for sustainability, product development economics, managing projects, design of a specific product (project).

References:
1. K. T. Ulrich and S. D. Eppinger, *Product Design and Development*. McGraw-Hill, 2004.
2. G. E. Dieter, *Engineering Design*, 2nded. McGraw Hill, 1991.
3. D. G. Ullman, *The Mechanical Design Process*, 4th ed. McGraw-Hill, 2010.
4. J. E Shigley, C. R Mischeke, and R. G. Budynas, *Mechanical Engineering Design*. Tata McGraw-Hill, 2004.
5. M. G. Luchs, S. Swan, and A. Griffin, *Design Thinking*. John Wiley & Sons, 2015.
6. B. W. Niebel and A. B. Draper, *Product Design and Process Engineering*. McGraw Hill, 1974.

ME6627D DESIGN OF PRESSURE VESSELS AND PIPING

Pre-requisites: ME6601D Advanced Mechanics of Solids /Equivalent

Total Hours: 39

L	T	P	C
3	0	0	3

Module 1: (14 hours)
Introduction, stresses in cylindrical, spherical and conical shells, dilation of pressure vessels, intersecting spheres, general theory of membrane stresses in vessels under internal pressure, torus under internal pressure, theory of thick cylinders and spheres, shrink fit stresses in built up cylinders, autofrettage of thick cylinders, thermal stresses in pressure vessels.
Stresses in flat plates: bending of rectangular plates with different edge conditions, bending of circular plates, plates with simply supported and clamped ends subjected to various loads, shell connections, heads and closures of various shapes.

Module 2: (14 hours)
Discontinuity stresses in pressure vessels: beam on an elastic foundation, infinitely long beam, semi-infinite beam, cylindrical vessel under axially symmetrical loading, slope and deflection considerations, discontinuity stresses in vessels, deformation and stresses in flanges.
Design and construction features: localized stresses and their significance, stress concentration at a variable thickness transition section in a cylindrical vessel, stress concentration about a circular hole in a plate subject to tension, elliptical openings, theory of reinforced openings, nozzle reinforcement, placement and shape, fatigue stress concentration, welded connections, bolted joints and gaskets.

Module 3: (11 hours)
Design of vessels under external pressure, design of tall vessels, design of supports, design of thick-walled high pressure vessels.
Piping design: piping stress analysis, flexibility factor and stress intensification factor, design of piping system as per standard piping codes.

References:

1. J. F. Harvey, *Theory and Design of Pressure Vessels*. CBS Publishers and Distributors, 1987.
2. L. E. Brownell and E. D. Young, *Process Equipment Design*.Wiley, 2009.
3. H. H. Bednar, *Pressure Vessel Design Hand Book*. Van Nostrand Reinhold, 1986.
4. B. C. Bhattacharyya, *Introduction to Chemical Equipment Design: Mechanical Aspects*.CBS Publishers and Distributors, 2008.
5. Bureau of Indian Standards, *Indian Standard Code for Unfired Pressure Vessels*. IS:2825,1969.
6. American Society of Mechanical Engineers, *Boiler and Pressure Vessel Code*, Section VIII, ASME, 2015.
7. American Society of Mechanical Engineers, *American Standard Code for Pressure Piping*, ASME, B31.1, 2007.

ME6628D THEORY OF PLASTICITY: FUNDAMENTALS AND COMPUTATIONAL METHODS

Pre-requisites: ME6601D Advanced Mechanics of Solids / Equivalent

Total Hours: 39

L	T	P	C
3	0	0	3

Module 1: (13 hours)
Review of theory of elasticity: mathematical preliminaries, stress and strain tensor, transformation laws, principal stress and strain, Mohr's circle, equilibrium equations, strain-displacement relations, compatibility conditions, stress-strain relations, general problem formulation and solution strategies.
Introduction to the theory of plasticity: experimental observations on behaviour of metals under uniaxial loading, true stress-true strain relations, effect of work hardening, empirical stress-strain relationships.

Module 2 (13 hours)
Yield criterion: fundamentals, experimental observations, Tresca and von Mises criterion, stress space representation, yield surface for work hardening materials; stress-strain relations in the plastic range: Prandtl-Reuss, Levy-Mises and St. Venant's stress-strain relations, plastic potential, principle of maximum work dissipation; unloading criterion; plastic instability; classical methods for solution: slip line field theory and bound theorems.

Module 3 (13 hours)
Computational Plasticity: basics of finite element method, nonlinear analysis, convergence and tolerance, radial-return algorithm, implementation of stress-strain relations: perfectly plastic, isotropic hardening and kinematic hardening materials, unloading detection, volumetric locking and mixed formulation.

References:

1. J. Chakrabarty, *Theory of Plasticity*, 3rd ed. Butterworth-Heinemann, 2011.
2. W. Johnson and P. B. Mellor, *Engineering Plasticity.*McGraw-Hill, 1987.
3. O. Hoffman and G. Sachs, *Introduction to the theory of Plasticity for Engineers*. McGraw-Hill, 1953.
4. R. Hill, *The Mathematical Theory of Plasticity*. Oxford University Press, 2009.
5. F. Dunne and N. Petrinic, *Introduction to Computational Plasticity*, Oxford University Press, 2005.
6. M. A. Crisfield, *Non-linear Finite Element Analysis of Solids and Structures*, Vol. 1: *Essentials*. John Wiley & Sons, 1994.

ME6629D CONTINUUM MECHANICS

Pre-requisites: ME6601D Advanced Mechanics of Solids / Equivalent

L	T	P	C
3	0	0	3

Total Hours: 39

Module 1: (12 hours)
Tensor algebra and calculus: continuum hypothesis and concept of field, scalar, vectors and second order tensors, tensor formalism and notational conventions, algebra of tensors, tensor transformation, tensor calculus: time derivative, gradient operator, directional derivative.

Module 2: (15 hours)
Kinematics of a continuum: displacement field, displacement and deformation gradients, rotation and strain tensors for infinitesimal deformation, finite deformation, polar decomposition, Lagrangian and Eulerian measures of strain.
Stress and integral formulation of general principles: stress tensor, principles of linear and angular momentum, conservation of mass, energy equation, entropy inequality.

Module 3 (13 hours)
Constitutive Relationships: the elastic solid, infinitesimal theory of elasticity: linear isotropic and anisotropic materials, finite deformation theory for isotropic materials, Newtonian fluids: inviscid and linear viscosity flows.

References:

1. W. M. Lai, D. Rubin, and E. Krempl, *Introduction to Continuum Mechanics*, 4th ed. Butterworth-Heinemenn, 2015.
2. J. N. Reddy, *An Introduction to Continuum Mechanics*, 2nd ed. Cambridge University Press, 2016.
3. D. S. Chandrasekharaiah and L. Debnath, *Continuum Mechanics*. Academic Press, 1994.

ME6330D EXPERIMENTAL STRESS ANALYSIS

Pre-requisites: ME6601D Advanced Mechanics of Solids / Equivalent

L	T	P	C
3	0	0	3

Total Hours: 39

Measure the stresses and strains in solids using photo-elastic methods.

Module 1: (13 hours)

Overview of theory of elasticity: analysis of stress at a point and strain at a point, governing equations for three dimensional elasticity problem, solution to plane stress and plane strain problems, Airy's stress function approach for solving plane elasticity problems, forms of stress function in polar coordinates, stress concentration at a circular hole in tension field; principal stresses and principal strains, prediction of failures; overview of experimental stress analysis.

Module 2: (13 hours)

Strain measurements: strain and its relation to experimental determinations, types of strain gauges: mechanical strain gauges, optical strain gauges, inductance strain gauges, electrical resistance strain gauges; strain sensitivity in metallic alloys; gauge construction-strain gauge adhesives and mounting methods; gauge sensitivities and gauge factor; performance characteristics of foil strain gauges; temperature compensation; strain gauge circuits: potentiometer, Wheatstone bridge circuits; strain rosettes: rectangular and delta rosette.

Theory of brittle coating method: coating stresses, failure theories, brittle coating patterns, crack detection, ceramic based and resin based brittle coatings, test procedures for brittle coating analysis, analysis of brittle coating data.

Module 3: (13 hours)

Two-dimensional photo-elasticity, photo-elastic materials, concept of light, photo-elastic effects, stress optic law, transmission photo-elasticity, Jones calculus, plane and circular polariscopes, Interpretation of fringe pattern, isoclinics, isochromatics, effects of stressed model in a plane polariscope and circular polariscope, dark field and light field arrangements, calibration of photo-elastic materials, compensation and separation techniques, introduction to three-dimensional photo-elasticity, stress freezing.

References:

1. J. W. Dally and W. E. Riley, *Experimental Stress Analysis*, 3rd ed. McGraw-Hill, 1991.
2. R. G. Budynas, *Advanced Strength and Applied Stress Analysis*, 2nd ed. McGraw-Hill, 1999.
3. L. S. Srinath, M. R. Raghavan, K. Lingaiah, G. Garghesha, B. Pant, and K. Ramachandra, *Experimental Stress Analysis*. Tata McGraw-Hill, 1984.
4. S. P. Timoshenko and J. N. Goodier, *Theory of elasticity,* 3rd ed. McGraw-Hill, 2017.

ME36631D FRACTURE MECHANICS AND FATIGUE

Pre-requisites: Nil

L	T	P	C
3	0	3	3

Total hours: 39

Module 1:Linear Elastic Fracture Mechanics(13 hours)

Introduction; historic over view of fracture mechanics, atomistic calculation of material strength; effect of flows on strength of a material; Griffith energy balance approach: Irwin's modification to the Griffith theory; R-curve approach; stress intensity factor approach; I, II & III modes of fracture; crack tip plasticity; Irvin approach; strip yield model; mixed mode problems; propagation of angled crack; FAD diagrams.

Testing of K_{IC}; ASTM E 399 standard; K-R curve testing,

Module 2:Elasto Plastic Fracture Mechanics(13 hours)

Elasto-plastic fracture mechanics: J integral,nonlinear energy release rate, path independence of J integral; J as stress intensity parameter; crack tip opening displacement approach, relationship between J and CTOD, J integral testing of materials; CTOD testing of materials; two-parameter fracture models:elastic T-stress; J-Q failure theories, limitations of two-parameter fracture mechanics models.

Module 3: Fatigue analysis and design (13 hours)

Design of components in fatigue loading, infinite life approach, S-N curve, factors affecting endurance limit, theories of failure in fatigue.

Finite life approach: low-cycle fatigue and high-cycle fatigue, Coffin-Manson law and Basquin's law, cyclic stress strain curve.

Fatigue crack propagation: empirical fatigue crack growth equations, Paris law, crack closure mechanisms, fatigue threshold,effect of environmental conditions of fatigue threshold, variable amplitude loading and fatigue-crack retardation, micro-mechanisms of fatigue; testing of fatigue crack growth, life prediction in fatigue.

Environmental-assisted cracking: stress corrosion cracking, hydrogen embrittlement.

References:

1. T. L. Anderson,*Fracture mechanics*, 3rd ed.CRC Press, 2005.
2. H. L. Ewalds andR. J. H. Wanhill, *Fracture Mechanics*. Edward Arnold Edition, 1984.
3. D. Broek, *Elementary Engineering Fracture Mechanics*, 3rd ed. Martinus Nijhoff Publishers, 2012.
4. K.Hellan, *Introduction to Fracture Mechanics*. McGraw Hill, 1985.
5. P. Kumar, *Elements of Fracture Mechanics*. Tata McGraw Hill, 2009.
6. R. I.Stefen, A. Fatemi, R. R. Stephens, and H. O. Fuchs,*Metal Fatigue in Engineering*, 2nd ed. Wiley, 2012.

ME6632DROBOTICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (12 hours)
Introduction to robotics and transformations: brief history, types and applications of robots, present status and future trends in robotics, robot configurations and concept of work space, types of actuators and sensors in robotics, types of grippers; basic of kinematics, coordinate frames and transformations, position and orientation of rigid bodies, planar and spatial mechanism description, homogenous transformations, examples.

Module 2: (12 hours)
Introduction to robotic manipulator kinematics and statics: Denavit-Hartenberg (DH) notation, forward and inverse kinematic analysis, solvability, algebraic vs. geometric approach, examples, case studies on modeling real robot mechanisms; Pipers solution; linear and rotational velocity of rigid bodies: velocity propagation from link to link, Jacobian, singularities; static forces in manipulators; Jacobians in force domain, examples.

Module 3: (15 hours)
Robotic manipulator dynamics: acceleration of a rigid body, mass distribution, iterative Newton-Euler dynamic formulation; Langrange-Euler formulation, dynamic equations for multiple degrees of freedom robot; trajectory planning and control of manipulators, general considerations in path description and generation, joint-space schemes, Cartesian space schemes; collision-free path planning; manipulator control systems, nonlinear and time varying systems, multi-input and multi-output control systems, PID control scheme, force control of manipulators.

References:
1. J. J. Craig,*Introduction to Robotics, Mechanics and control*, 2nded. Addison–Wesley, 1999.
2. R.K.Mittal and I.J.Nagarath, *Robotics and Control*, Tata McGraw Hill, 2003.
3. S. B.Niku,*Introduction to Robotics, Analysis, Systems and applications*, 2nd ed. Prentice Hall India, 2010.
4. M. W.Spong and M.Vidyasagar, *Robot Dynamics and Control*, John Wiley & Sons, 1989.
5. K. S. Fu, R. C. Gonzales, and C. S. G.Lee, *Robotics Control, Sensing, Vision and Intelligence*, McGraw Hill, 1987.
6. R. P. Paul,*Robot Manipulators: Mathematics, Programming, and Control*. The MIT Press, 1979
7. R. J. Schilling,*Fundamentals of Robotics, Analysis and Control*. Prentice Hall of India, 1996.

ME6633DMECHATRONICS SYSTEMS AND FLUID POWER AUTOMATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1:(12 hours)
Introduction to mechatronics systems: key elements in mechatronics, advanced approaches in mechatronics, real-time interfacing; elements of data acquisition system; actuators and sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force, strain and temperature, flow sensors, fiber optic sensors, magnetostrictive transducer, selection of sensors, microsensors in mechatronics.

Module 2: (15 hours)
Introduction to signals, system and controllers: introduction to signals, system and control, system representation, linearization, time delays, measures of system performance; closed loop controllers: PID controller, adaptive control; introduction to microprocessors, micro-controllers, programmable logic controllers: components, PLC programming; sensors for condition monitoring; mechatronics control in automated manufacturing**.**

Module 3: (12 hours)
Drives and mechanisms of an automated system: drives: stepper motors, servo drives, ball screws, linear motion bearings, cams, systems controlled by camshafts, electronic cams, indexing mechanisms, tool magazines, and transfer systems.
Hydraulic and pneumatic systems: flow, pressure and direction control valves, actuators, and supporting elements, hydraulic power packs and pumps, design of hydraulic circuits; pneumatics: system components and graphic representations, design of pneumatic circuits.

References:

1. D. Shetty, R. A.Kolk, *Mechatronics System Design*, 2nd ed. Thomson Learning, 2001.
2. M. P. Groover, *Automation, Production systems and Computer integrated manufacturing,* 4th ed. Pearson Education,2016.

1. W.Bolton, *Mechatronics*, 4th ed. Pearson Education, 2004.
2. HMT Ltd*, Mechatronics*. Tata McGraw Hill, 1998.
3. B.P. Singh, *Microprocessors and Microcontrollers*,1st ed. Galgotia Publications, 2004.
4. F. D.Petruzella, *Programmable Logic Controllers*,3rd ed. Tata McGraw Hill, 2010
5. J. F. Blackburn, G. Reethof, and J. L. Shearer, *Fluid Power Control*. MIT Press, 1966.
6. A. Esposito, *Fluid Power with Applications*, 6th ed. Pearson Education, 2003.
7. T. O. Boucher, *Computer Automation in Manufacturing:An Introduction*, 1st ed. Chapman and Hall, 1996.

ME6634D ROTOR DYNAMICS

Pre-requisites: ME6602D Theory of Vibrations

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (13 hours)
Review of vibration; forced vibration of MDOF system, modal decomposition of undamped and damped systems.
Free lateral response of simple rotor models; coordinate systems, gyroscopic couples, dynamics of a rigid rotor on flexible supports, isotropic flexible supports, dynamics of rotors with and without considering gyroscopic effect and elastic coupling.

Module 2: (13 hours)
Rigid rotor on anisotropic flexible supports, forward and backward whirl, natural frequency maps, effect of damping in supports, anisotropic support damping, simple model of a flexible rotor.
Forced lateral response and critical speeds; simple models of rotors with out-of-balance forces and moments.

Module 3: (13 hours)
Response of a rigid rotor on isotropic supports to out-of-balance forces, response of a Jeffcott rotor to out-of-balance forces and moments, response of a rigid rotor on anisotropic supports to out-of-balance forces and moments; complex rotor models.

References:
1. M. I.Friswell, J.E.T.Penny, S.D.Garvey, and A. W. Lees, *Dynamics of Rotating Machines*. Cambridge University Press, 2010.
2. G.Genta, *Dynamics of Rotating Systems*. Springer, 2005.
3. J.S.Rao, *Rotor Dynamics*. Wiley Eastern, 1985.
4. J. Vance, F. Zeidan, and B. Murphy, *Machinery Vibration and Rotor Dynamics*. John Wiley & Sons, 2010.

ME6635D ANALYTICAL AND NONLINEAR DYNAMICS

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (13 hours)
Overview of Newtonian mechanics: Newton's second law of motion, moment of a force and angular momentum, work and energy; systems of particles and rigid bodies.
Generalized coordinates and degrees of freedom, holonomic and nonholonomic constraints.
Virtual work: virtual displacements and virtual work, constraint forces, principle of virtual work, D'Alembert's principle, generalized forces; Hamilton's principle, Lagrange's equations of motion, Lagrange multipliers.

Module 2: (13 hours)
Phase space: phase diagram for the pendulum equation, canonical forms for planar systems, fixed points and stability, linear stability analysis, potentials, limit cycles.
Bifurcation theory: saddle-node bifurcation, transcritical bifurcation, pitchfork bifurcation, Hopf bifurcation, multistability and bistability; perturbation methods for almost periodic solutions: regular perturbation, Poincare-Linstedt method, method of averaging.

Module 3: (13 hours)
Heuristic methods: harmonic balance, equivalent linearization, Galerkin method.
Forced oscillations: harmonic and subharmonic response, stability and entrainment.
Nonlinear discrete dynamical systems: The Tent map and graphical iterations, fixed points and periodic orbits, logistic map, bifurcation diagram and Feigenbaum number; fractals: construction of simple examples, calculating fractal dimensions.

References:

1. L. Meirovirtch, *Principles and Techniques of Vibrations*, Prentice Hall, 1997.
2. D. T. Greenwood, *Principles of Dynamics*, 2nd ed. Prentice Hall, 1987.
3. D. T. Greenwood,*Advanced Dynamics*, Cambridge University Press, 2006.
4. D. W. Jordan and P. Smith, *Nonlinear Ordinary Differential Equations*, 4thed. Oxford University Press, 2007.
5. S.H.Strogatz, *Nonlinear Dynamics and Chaos*, Levant Books, 2007.
6. S. Lynch, *Dynamical Systems with Applications using Maple*, 2nd ed. Birkhäuser Boston, 2010.
6. A. H. Nayfeh and B.Balachandran, *Applied Nonlinear Dynamics*. Wiley VCH, 1995.
7. J. M. T. Thomson and H.B. Stewart, *Nonlinear Dynamics and Chaos*, 2nd ed. Wiley-Blackwell, 2001.
8. F. C.Moon, *Chaotic and Fractal Dynamics*, 2nd ed. Wiley VCH, 1992.

ME6336D COMPUTERGRAPHICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

TotalHours:39

Module1: (13hours)
Introduction to computer graphics: overview of computer graphics; mathematics for computer graphics; representing and interfacing with pictures; description of graphic devices; raster scan graphics; algorithms for generating line, circle and ellipse; polygon filling; fundamentals of anti-aliasing; two-dimensional and three-dimensional transformations: scaling; shearing; rotation; reflection; translation; affine and perspective geometry: orthographic; axonometric and oblique projections; perspective transformations.

Module2: (13hours)
Plane curves; non-parametric and parametric curves: space curves; representation of space curves; cubic spline; Bezier curves; B-spline curves; NURBS.

Module3: (13hours)
Surface description and generation: surface of revolution; sweep surface; linear Coons surface; Bezier surface; B-Spline surface; B-Spline surface filling.
Introduction to solid modeling; hidden lines and hidden surfaces.

As part of the course requirement, computer program oriented term projects and term papers are essential.

References:

1. D.F. Rogers and J.A. Adams, *Mathematical Elements for Computer Graphics,* 2nd ed. Tata McGraw Hill, 2009.
2. D.F. Rogers, *Procedural Elements for Computer Graphics,* 2nd ed. Tata McGraw Hill,1997.
3. D. Hearn and M.P. Baker, *Computer Graphics,*2nd ed. Prentice Hall of India,2007.
4. J.D. Foley,A.V. Dam,S.K. Feiner, and J.F. Hughes, *Computer Graphics: Principles and Practice in C,* 2nd ed. Addison-Wesley Professional,1995.
5. M.E.Mortenson, *Geometric Modeling,* 2nd ed. John Wiley & Sons,1997.