M.Tech.

IN

MACHINE DESIGN

CURRICULUM AND SYLLABI

(Applicable from 2023 admission onwards)

तमसो मा ज्योतिर्गमय

Department of Mechanical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech. in Machine Design

PEO1	Graduates apply their in-depth and advanced knowledge for fostering skills of analysing, formulating, defining and solving complex engineering problems in the areas of solid mechanics and dynamics for productive and successful careers.
PEO2	Graduates demonstrate innovative and independent research work in academia/industry/R&D to enhance the knowledge base in solid mechanics and dynamics and to disseminate the knowledge.
PEO3	Graduates exhibit a high level of professionalism, integrity, social responsibility and life-long independent learning ability.

Programme Outcomes (POs) of M.Tech. in Machine Design

PO1	Ability to independently carry out research/investigation and development work to solve practical problems.
PO2	Ability to write and present a substantial technical report/document.
PO3	Ability to demonstrate mastery in solid mechanics, dynamics and machine design at a level higher than the requirements in the appropriate bachelor program.
PO4	Ability to acquire and share in-depth knowledge in the area of solid mechanics, dynamics and machine design.
PO5	Ability to analyse complex problems in the field of solid mechanics, dynamics and machine design critically and arrive at optimal solutions.
PO6	Ability to use modern computer/software tools to model and analyse problems related to solid mechanics, dynamics and machine design.

CURRICULUM

Total credits for completing M.Tech. in Machine Design is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	23
2.	Program Electives (PE)	15
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Title of Course	L	T	P	O	C	Category
1.	ME6601E	Mathematical Methods in Mechanical Design	3	1	0	8	4	PC
2.	ME6602E	Advanced Mechanics of Solids	3	0	0	6	3	PC
3.	ME6603E	Theory of Vibrations	3	0	0	6	3	PC
4.		Elective 1	3	0	0	6	3	PE
5.		Elective 2	3	0	0	6	3	PE
6.	ME6691E	Design Engineering Laboratory	0	0	3	3	2	PC
7.		Institute Elective	2	0	0	4	2	IE
		Total	17	1	3	39	20	--

Semester II

Sl. No.	Course Code	Title of Course	L	T	P	O	C	Category
1.	ME6611E	Finite Element Method	3	0	0	6	3	PC
2.	ME6612E	Advanced Methods in Engineering Design	3	1	0	8	4	PC
3.		Elective 3	3	0	0	6	3	PE
4.		Elective 4	3	0	0	6	3	PE
5.		Elective 5	3	0	0	6	3	PE
6.	ME6692E	CAD Laboratory	0	0	3	3	2	PC
7.	ME6693E	Product Design Laboratory	0	0	3	3	2	PC
8.	ME6694E	Project Phase I	0	0	0	6	2	PC
		Total	15	1	6	44	22	--

Semester III

Sl. No.	Course Code	Title of Course	L	T	P	O	C	Category
1.	ME7695E	Project Phase II	0	0	0	9	3	PC
2.	ME7696E	Project Phase III	0	0	0	45	15	PC
		Total	0	0	0	54	18	--

Semester IV

Sl. No.	Course Code	Title of Course	L	T	P	O	C	Category
1.	ME7697E	Project Phase IV	0	0	0	45	15	PC
		Total	0	0	0	45	15	--

List of Electives

Sl. No.	Code	Course Name	L	T	P	O	C
1	ME6621E	Rigid Body Mechanics	3	0	0	6	3
2	ME6622E	Behaviour and Selection of Materials	3	0	0	6	3
3	ME6623E	Industrial Tribology	3	0	0	6	3
4	ME6624E	Design of Electro-Mechanical Systems	3	0	0	6	3
5	ME6625E	Nonlinear Dynamics	3	0	0	6	3
6	ME6626E	Product Design	3	0	0	6	3
7	ME6627E	Design of Pressure Vessels and Piping	3	0	0	6	3
8	ME6628E	Plasticity: Fundamentals and Computational Methods	3	0	0	6	3
9	ME6629E	Continuum Mechanics	3	0	0	6	3
10	ME6630E	Experimental Stress Analysis	3	0	0	6	3
11	ME6631E	Fracture Mechanics and Fatigue	3	0	0	6	3
12	ME6632E	Robotics	3	0	0	6	3
13	ME6633E	Mechatronics Systems and Fluid Power Automation	3	0	0	6	3
14	ME6634E	Rotor Dynamics	3	0	0	6	3
15	ME6635E	Analytical and Nonlinear Dynamics	3	0	0	6	3
16	ME6636E	Computer Graphics	3	0	0	6	3
17	ME6637E	Principles of Vibration Control	3	0	0	6	3
18	ME6638E	Multibody Dynamics and Applications	3	0	0	6	3
19	ME6639E	Theory of Mechanisms	3	0	0	6	3
20	ME6640E	Gear Design	3	0	0	6	3
21	ME6641E	Data Driven Techniques for Mechanical Engineering	3	0	0	6	3
22	ME6642E	Vibration of Continuous System	3	0	0	6	3
23	ME6643E	Applied Finite Element Analysis	2	0	2	5	3
24	ME6644E	Introduction to Vehicle Dynamics	3	0	0	6	3
25	ME6645E	Material Selection in Mechanical Design	3	0	0	6	3
26	ME6646E	Bio-Inspired Design	3	0	0	6	3
27	ME6647E	Science of Classical Musical Instruments	3	0	0	6	3

List of Institute Electives

Sl. No.	Code	Course Name	L	T	P	O	C
1	IE6001E	Entrepreneurship Development	2	0	0	4	2
2	ZZ6002E	Research Methodology	2	0	0	4	2
3	MS6174E	Technical Communication and Writing	2	1	0	3	2

Syllabi for the M. Tech. Programme in MACHINE DESIGN

ME6601E MATHEMATICAL METHODS IN MECHANICAL DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	1	0	8	4

Total Lecture Sessions: 52

Course Outcomes:

CO1: Apply mathematical concepts related to differential equations, linear algebra, field theory, and numerical methods to solve engineering problems.

CO2: Utilize matrix algebra and linear transformations to solve systems of linear equations and analyze linear transformations in engineering contexts.

CO3: Use Techniques like integrating factors and separation of variables to solve first-order ODEs and Apply various analytical methods for solving second-order ODEs, including homogeneous and nonhomogeneous linear equations with constant coefficients.

CO4: Identify different types of PDEs and employ various techniques including the separation of variables to solve linear PDEs.

CO5: Determine approximates solutions of linear algebraic equations, ODEs, and PDEs using different numerical methods.

CO6: Use software tools to solve ODEs numerically, visualize solutions, and verify analytical results.

Linear Algebra

Vector Space: Dot Product, Norm, Orthogonality, Normalization; Definition of Vector Space, Inner Product Space, Span and Subspace, Linear Dependence; Bases, Expansion, Dimensions, Orthogonal Bases, Gram-Schmidt Orthogonalization.

Linear Algebraic Equations – Elementary Row/Column Operations, Existence/Uniqueness of Solutions; Change of Basis, Vector Transformation.

The Eigenvalue Problem – Eigenvalues and Eigenvectors of Matrices and their Properties; Diagonalization; Applications.

Ordinary Differential Equations

1^{st} order ODEs – Integrating factor Method, Separation of Variable Technique.

2^{nd} order ODEs – Linear Dependence and Linear Independence, General Solution of Homogeneous Equations; Solution of Homogeneous Equation with Constant Coefficients (Exponential Solutions, Higher-Order Equations (n>2), Repeated Roots). Solution of Homogeneous Equation with Nonconstant Coefficients (Cauchy-Euler Equation, Reduction of Order, Factoring the Operator - optional, if time permits); Solution of Nonhomogeneous Equation (General Solution, Undetermined Coefficients); Solution of Nonhomogeneous Equation (Variation of Parameters); System of Linear Differential Equations (Existence and Uniqueness for Linear First-Order Systems, Solution by Elimination); The Sturm-Liouville Theory; Power Series Solutions; Singular Points, Method of Frobenius.

Partial Differential Equations

First order PDES – Semi linear and Quasilinear Equations in Two Independent Variables; Cauchy Problem; Monge Strip and Charpi Equations.

Partial Differential Equations: Second order PDES – Classification, Modelling of Vibrating String and Wave Equation; Solution by Separation of Variables; D'Alembert's Solution of the Wave Equation

Field Theory

Divergence, Gradient, Curl; Divergence Theorem; Stokes' Theorem; Green's Theorem; Irrotational Fields.

Topics in Numerical Methods

Numeric Linear Algebra – Gauss Elimination and Gauss-Jordan Elimination, Echelon Form, Pivoting; LU Decomposition and Cholesky Method; Gauss-Seidel/Jacobi Iterative Method; Condition Number, Minimum

Norm and Least Square Error Solutions; Iterative Methods to Find Eigenvalues and Eigenvectors of Symmetric Matrices; Newton-Raphson Method for a System of Nonlinear Equations.
ODEs – Euler's and Runge-Kutta Method; Predictor-Corrector Method.
PDEs – Elliptic PDE, Parabolic PDE, Hyperbolic PDE.

*** Applications using Software**

References:

[1] Greenberg, M. D., 1998, *Advanced Engineering Mathematics*, Pearson Education India
[2] Kreyszig, E., Stroud, K., and Stephenson, G., 2008, *Advanced Engineering Mathematics*, John Wiley and Sons, Inc
[3] Strang, G., 2006, *Linear Algebra and its Applications*, Belmont, CA: Thomson, Brooks/Cole
[4] Hoffman, K., and Kunze, R., 2012, *Linear Algebra*, PHI Learning
[5] Coddington, E. A., and Levinson, N., 2018, *Theory of Ordinary Differential Equations*, Tata McGraw-Hill
[6] Prasad, P., and Ravindran, R., 1985, *Partial Differential Equations*, New Age International
[7] Sneddon, I. N., 2006, *Elements of Partial Differential Equations*, Courier Corporation
[8] Rao, K. S., 2010, *Introduction to Partial Differential Equations*, PHI Learning Pvt. Ltd.
[9] Yang, W. Y., Cao, W., Chung, T., and Morris, J., 2007, *Applied Numerical Methods Using MATLAB*, Wiley
[10] Chapra, S. C., 2010, *Numerical Methods for Engineers*, McGraw Hill

ME6602E ADVANCED MECHANICS OF SOLIDS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Define fundamental variables and parameters in solid mechanics.
CO2: Use the governing equations of elasticity to formulate problems in solid mechanics.
CO3: Formulate and solve two-dimensional problems in elasticity.
CO4: Solve elasticity problems using energy methods and polynomials.
CO5: Solve advanced problems in bending and torsion.
CO6: Formulate problems in plasticity using the basic concepts.

Fundamental Variables and Parameters
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, analogy with stress tensor – strain energy.

Governing Equations
Equations of equilibrium – kinematical relations – constitutive relations, Lame's constants – compatibility conditions – boundary conditions – Navier's equations – equations in polar coordinates.

Two-dimensional Problems
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 and Solutions using Polynomials
Energy theorems – principle of virtual work – minimum potential energy principle – use of energy theorems for calculating deflections and stresses – Solutions using polynomials, Airy's stress function – stress concentration problems.

Special Problems in Bending and Torsion
Special problems in bending: unsymmetric bending, shear centre – 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 – yield criteria for metals – plastic stress-strain relationships – Unloading and reloading: Bauschinger effect, isotropic and kinematic hardening.

References:
[1] Timoshenko, S. P., and Goodier, J. N., 2017, *Theory of Elasticity*, McGraw Hill
[2] Srinath, L. S., 2017, *Advanced Mechanics of Solids*, Tata McGraw Hill
[3] Sadd, M. H., 2014, *Elasticity: Theory, Applications and Numerics*, Academic Press
[4] Durelli, A. J., Philips, E. A., and Tsao, C. H., 1958, *Introduction to the Theoretical and Experimental Analysis of Stress and Strain*, McGraw Hill
[5] Tong, P., Chen, X., and Fung, Y. C., 2020, *Classical and Computational Solid Mechanics*, World Scientific
[6] Boresi, A. P., and Schmidt, R. J., 2009, *Advanced Mechanics of Materials*, Wiley
[7] Nambudiripad, K. B. M., 2018, *Advanced Mechanics of Solids - A Gentle Introduction*, Narosa
[8] Fenner, R. T., 1986, *Engineering Elasticity: Applications of Numerical and Analytical Techniques*, Ellis Hodwood
[9] Johnson, W., and Mellor, P. B., 1983, *Engineering Plasticity*, Van Nostrand Reinhold
[10] Chakrabarty, J., 2007, *Theory of Plasticity*, Butterworth-Heinemann

ME6603E THEORY OF VIBRATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Solve SDOF systems for free and forced vibrations.
CO2: Model and solve Two-DOF and MDOF vibration problems.
CO3: Formulate and solve problems in vibration of continuous systems.
CO4: Carry out approximate and numerical solutions of SDOF, Two-DOF, and MDOF systems.

Vibration of SDOF Systems
Introduction – Introduction to the course, Basic Concepts of Vibrations, Classification of Vibration, Fundamentals of Vibration
Free Vibration – Free Vibration of Undamped Systems; Free Vibration with Viscous Damping; Free Vibration with Viscous Damping: Logarithmic Decrement, Loss Coefficient; Free Vibration with Coulomb Damping, Free Vibration with Hysteretic Damping.
Harmonically Excited Vibration – Response of an Undamped System Under Harmonic Force; Response of a Damped System Under Harmonic Force; Response of a Damped System Under the Harmonic Motion of the Base; Response of a Damped System Under Rotating Unbalance; Forced Vibration with Coulomb Damping; Forced Vibration with Hysteresis Damping; Frequency Transfer Functions, Bode Diagrams; Whirling of Shaft; Vibration Measuring Instruments; Computational Exercises

Vibration of SDOF Systems General Forcing Conditions
Response Under a General Periodic Force; Response Under a Nonperiodic Force: Convolution Integral – Impulse Response, Step Response; Response Under a Nonperiodic Force: Convolution Integral – Rectangular Pulse, Triangular Pulse, Response Spectrum; Response Under a Nonperiodic Force: Laplace Transforms; Response Under a Nonperiodic Force: Fourier Transforms

Vibration of Two-Degrees-of-Freedom-Systems
Energy Method, Rayleigh Method, Introduction to Lagrange Equations; Applications of Lagrange Equations; Free-Vibration of Undamped Systems, Semidefinite Systems; Eigen Value Problem for Undamped-Free Vibration; Orthogonality, Expansion theorem; Normal modes and their properties; Response to initial excitation; Forced harmonic vibration; Vibration absorber.
Vibration of Multi-Degrees-of-Freedom-Systems: Matrix Formulation, Stiffness and Flexibility Influence Coefficients

Vibration of Continuous Systems
The Boundary-Value Problem for Strings; Longitudinal Vibration of a Bar or Rod; Torsional Vibration of Shafts; Lateral Vibration of Beams;

Determination of Natural Frequencies
Rayleigh's Method, Rayleigh-Ritz Method; Dunkerley's Formula. Computational Exercises.
Introduction to Random and Nonlinear Vibrations.

References:
[1] Thomson, W., 2003, *Theory of Vibration with Applications*, Prentice hall of India
[2] Meirovitch, L., 1986, *Elements of Vibration Analysis*, McGraw Hill
[3] Rao, S. S., 2004, *Mechanical Vibrations*, Pearson
[4] Den Hartog, J. P., 1985, *Mechanical Vibrations*, Courier Corporation

ME6691E DESIGN ENGINEERING LABORATORY

Pre-requisites: NIL

L	T	P	O	C
0	0	3	3	2

Total Sessions: 39

Course Outcomes:
CO1: Conduct studies using tribological instruments like pin-on-disc tribometer and four-ball tester.
CO2: Gain exposure to data acquisition using different sensors
CO3: Conduct vibration experiments using various instruments and systems.
CO4: Perform measurements using strain gauges and perform their calibration.
CO5: Learn basic devices and carry out studies in robotics.

Tribology (3): Measurement of friction and wear using pin-on-disc tribometer and four-ball wear tester; Study and Demonstration of Optical Profilometer and NanoIndenter.

Vibration (5): Data acquisition using accelerometer, laser displacement sensor, load cell; Experimental strain mapping using DIC; Free Vibration of SDOF spring-mass-damper system; Forced Vibration/Base Excited Vibration of SDOF spring-mass-damper system; Modal Analysis of Cantilever/Simply Supported Beam/Demonstration of mode shapes of a plate.

Metrology (1): Studies on form error.

Robotics (3): Studies on programmable logic controller (PLC), Familiarization with pneumatic and hydraulic hardware and circuits, Exercises on robots.

List of Experiments:
1. Friction and wear test using four-ball tester.
2. Friction and wear test using pin-on-disc tribometer.
3. Study and Demonstration of Optical Profilometer and NanoIndenter.
4. Data acquisition using accelerometer, laser displacement sensor, load cell.
5. Experimental strain mapping using DIC.
6. Free Vibration of SDOF spring-mass-damper system
7. Forced Vibration/Base Excited Vibration of SDOF spring-mass-damper system.
8. Modal Analysis of Cantilever/Simply Supported Beam/Demonstration of mode shapes of a plate.
9. Studies on form error.
10. Studies on programmable logic controller (PLC).
11. Familiarization with pneumatic and hydraulic hardware and circuits.
12. Exercises on robots.

References:

[1] Dally, J. W., and Riley, W. F., 1991, *Experimental Stress Analysis*, McGraw-Hill
[2] Srinath, L. S., Raghavan, M. R., Lingaiah, K., Gargesha, G., Pant, B., and Ramachandra, K., 1984, *Experimental Stress Analysis,* Tata McGraw-Hill
[3] Qiu, M., Chen, L., Li, Y., and Yan, J., 2016, *Bearing Tribology: Principles and Applications,* Springer
[4] Bobzin, K., Bartels, T., and Mang, T., 2011, *Industrial Tribology: Tribo-systems, Friction, Wear and Surface Engineering, Lubrication*, John Wiley and Sons
[5] Thomson, W., 2003, *Theory of Vibration with Applications*, Prentice hall of India
[6] Niku, S. B., 2001, *Introduction to Robotics: Analysis, Systems, Applications,* Prentice hall New Jersey
[7] Shetty, D., and Kolk, R. A., 2001, *Mechatronics System Design,* Thomson Learning

ME6611E FINITE ELEMENT METHOD

Pre-requisites: Knowledge of the basics of Theory of Elasticity

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Understand the basics and significance of finite element method.
CO2: Develop finite element formulation of one-dimensional problems.
CO3: Develop finite element formulation of two-dimensional problems.
CO4: Perform numerical integration and parametric mapping.
CO5: Solve problems using FEM by writing programs or with commercial software.

Fundamentals
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 – 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.

One-dimensional finite element analysis
Shape functions – finite element formulation – assembly and boundary conditions – continuity requirements – order of shape functions.

Two-dimensional finite element analysis
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.

Numerical integration and parametric mapping
Numerical integration: Newton-Cote’s methods and Gauss quadrature, advantages of Gauss quadrature – parametric mapping: super-parametric, sub-parametric and iso-parametric mapping – numerical integration in higher dimensions – applications.

Miscellaneous and advanced topics
Introduction to 3D FEM – finite element types – 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] Zienkiewicz, O. C., and Morgan, K., 2013, *Finite Elements and Approximation*, Dover Publications
[2] Reddy, J. N., 2019, *Introduction to the Finite Element Method*, McGraw-Hill Education
[3] Zienkiewicz, O. C., Taylor, R. L., and Zhu, J. Z., 2005, *The Finite Element Method: its Basis and Fundamentals*, Elsevier
[4] Cook, R. D., Malkus, D. S., Plesha, M. E., and Witt, R. J., 2001, *Concepts and Applications of Finite Element Analysis*, Wiley
[5] Bathe, K. J., 1996, *Finite Element Procedures*, Prentice-Hall of India

ME6612E ADVANCED METHODS IN ENGINEERING DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	1	0	8	4

Total Sessions: 52

Course Outcomes:

CO1: Understand the Design fundamentals, material selection process and apply design guidelines for manufacturing processes like casting, welding, forming machining and powder metallurgy.

CO2: Analyze various products through case studies and use various product development tools and methods to propose conceptual model and provide solution for sustainable product design

CO3: Determine the reliability of products and machine components using failure data, probabilistic concepts, and various failure models.

CO4: Analyze specific failure cases and apply the statistical theories required for performing sensitivity analysis in design and create empirical models to determine system output.

Material Selection for matching materials to design, stiffness limited design, strength limited design, fracture limited design, Product Development Tools- TRIZ, QFD, Product Architecture, Design Case Studies, Design recommendations for Strategic Design using various DFM Guidelines such as Design for Casting, Design for sheet metal, Design for machining, Design for Forging, Design for welding, Design for Assembly, Design recommendation for fasteners, Environmental objectives, Lifecycle Assessment, Design to minimize material usage, Design for disassembly, Design for recyclability, Design for energy efficiency – Design to regulations and standards

Failure distributions, hazard models exponential, Rayleigh, Weibull, Normal and Lognormal distributions, MTTF, MTBF. Reliability of systems – series and parallel configurations - Reliability improvement, redundancy, Reliability of complex configurations, Reliability of three-state devices, Physical reliability models, Design for reliability, Design for maintainability-Availability, Failure data analysis, Reliability Testing, Identifying failure distributions– parameter estimation. Approaches to intelligent control, Concept of artificial neural network and its models - Case studies

Introduction to variation in Engineering Design: Propagation of error, protecting design against variations, Estimation of statistical parameters, statistical bias, robustness, determining the variation of inputs using simulation approach, Modelling variation of complex systems, Desirability, Failure Analysis: sources of failure, methodology of failure analysis, fractography, metallography, polymer failures, failure of ceramics and glass, failure analysis case studies.

References:

[1] Crane, F. A. A., Charles, J. A, and Furness, J., 1997, *Selection and Use Of Engineering Materials*, Elsevier

[2] Ashby, M. F., Shercliff, H., and Cebon. D., 2018, *Materials: Engineering, Science, Processing And Design*, Butterworth-Heinemann

[3] Shigley, J., and Mischke, C., 2003, *Mechanical Engineering Design,* McGraw Hill

[4] Kutz, M., 2007, *Environmentally Conscious Mechanical Design*, John Wiley & Sons

[5] Dieter, G., and Schmidt, L. C., 2012, *Engineering Design,* McGraw Hill

[6] Rao, S. S., 1992, *Reliability-based Design*, McGraw-Hill

[7] Srinath, L. S., 2005, *Reliability Engineering,* East-West Press

[8] Ebeling, C. E., 2019, *An Introduction to Reliability and Maintainability Engineering*, Waveland Press

[9] Breneman, J. E., Sahay, C., and Lewis, E. E., 2022, *Introduction to Reliability Engineering*, John Wiley & Sons

ME6692E CAD LABORATORY

Pre-requisites: NIL

Total Sessions: 39

L	T	P	O	C
0	0	3	3	2

Course Outcomes:
CO1: Model mechanical systems and components using a CAD software.
CO2: Perform finite element analyses of mechanical systems using a commercial software.
CO3: Identify potential sources of inaccuracy in finite element analysis and take corrective actions.
CO4: Select suitable analysis type(s) and parameters for a particular application.
CO5: Use multi-body dynamics software to perform static, kinematic and dynamic analysis of systems.

List of Experiments:

Computer Aided Design:
1. Part Modeling, Assembly and Mechanism Modeling using CAD Software (demonstration only)

Finite Element Analysis:
2. Static Structural Analysis
3. Coupled Thermal Stress Analysis
4. Meshing of a Complicated 3-D Model Imported from a CAD Software
5. Modal Analysis to obtain Natural Frequencies
6. Buckling Analysis
7. Elasto-Plastic Analysis
8. Contact Analysis – Sphere-on-Flat Problem
9. Transient Structural Analysis
10. Impact Analysis

Multi-body Dynamics Analysis:
11.a. Kinematic Analysis of Four-bar Mechanism
11.b. Kinematic Analysis of Quick-Return Mechanism
12.a. Static Analysis of four bar mechanism
12.b. Dynamic Analysis of a Four-bar Mechanism

References:

[1] Popov, E. P., 2015, *Engineering Mechanics of Solids*, Pearson Education India
[2] Goodier, J. N., and Timoshenko, S. P., 1970, *Theory of Elasticity*, McGraw-Hill
[3] Sadd, M. H., 2014, *Elasticity: Theory, Applications and Numerics*, Academic Press
[4] Thompson, M. K., and Thompson, J. M., 2017, *ANSYS Mechanical APDL for Finite Element Analysis*, Butterworth-Heinemann
[5] Johnson, K. L., 1987, *Contact Mechanics*, Cambridge University Press
[6] Zienkiewicz, O. C., Taylor, R. L., and Zhu, J. Z., 2013, *The Finite Element Method: its Basis and Fundamentals*, Butterworth-Heinemann
[7] Rattan, S. S., 2014, *Theory of Machines*, Tata McGraw-Hill Education
[8] ANSYS Mechanical APDL Documentation
[9] MSC ADAMS Product Documentation

ME6693E PRODUCT DESIGN LABORATORY

Pre-requisites: NIL

Total Sessions: 39

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Familiarize mechanical product design principles and methodologies.
CO2: Gain practical experience in prototyping and testing mechanical products.
CO3: Enhance problem-solving and critical-thinking skills through design challenges.

List of Experiments

Product Dissection on different products such as Power Tools, Blender, Pumps, Dispensing Machines, Desktop Printers etc. to understand the following -

1. Working principle and application –-Disassembly plan -Parts and function
2. Design concept - Using TRIZ for Concept Generation and Selection of Design Concept
3. Determine the Product modules/assembly/subassemblies
4. Functional decomposition
5. Geometrical layout & Product architecture
6. Design synthesis
7. Design embodiment
8. Alternative design of the product for the same function
9. Develop performance requirements, prototyping.

References:

[1] Ulrich, K. T., and Eppinger, S. D., 2011, *Product Design and Development*, McGraw-Hill

[2] Dieter, G., and Schmidt, L. C., 2012, *Engineering Design*, McGraw Hill

[3] Ullman, D. G., 2009, *The Mechanical Design Process*, McGraw-Hill

[4] Luchs, M. G., Swan, S., and Griffin, A., 2015, *Design Thinking: New Product Development Essentials from the PDMA*, John Wiley & Sons

ME6694E PROJECT PHASE I

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Understand the process of reviewing and recording the literature
CO2: Understand the process of identification of the project problem
CO3: Apply the learning to define the problem and problem environment/boundary conditions
CO4: Develop a focused research learning, presentation, and communication

Project Phase I is normally an initiation into the project.

Each student shall identify a topic of interest related to the core/elective courses undergone in the first semester of the M. Tech. programme. He/she shall get the topic approved by the project guide in the concerned area of specialization. The student is expected to conduct a literature survey. A mid semester evaluation shall be done by the guide. At the end of the semester the student shall present the project problem and the related literature in the presence of the duly constituted evaluation committee. Grade will be awarded based on the student's work and presentation.

ME7695E PROJECT PHASE II

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem (This primarily pertains to the objective of Phase 2)
CO2: Analyse and Identify a suitable research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to develop algorithms and solve the problem.
CO4: Analyze and interpret the results using tables and figures for visualization
CO5: Compile and construct a report by employing the techniques of academic writing critical analysis, and defend the thesis
CO6: Publish the findings in reputed journals, conferences or apply for patents

Project Phase II can be an extension of Phase I or internship outside during the summer semester break. Students shall continue to work on the problem identified in the project phase I or undergo internship outside. Students shall identify the methodology, apply for a preliminary work. The work should be suitable for communicating to a conference. The student shall submit a report. All the projects will be evaluated by a duly constituted committee.

ME7696E PROJECT PHASE III

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Choose an area of research, summarize research papers and select a research problem.
CO2: Find an appropriate research methodology for the problem chosen.
CO3: Outline the methods/tools to solve the problem.
CO4: Formulate an appropriate model for solving the problem.

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 pilot study, redefine the project based on pilot study, decide on the appropriate research design, generate data/collect data, develop the algorithm and code, and obtain preliminary results 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.

ME7697E PROJECT PHASE IV

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Develop algorithms/solution procedures to solve the problem.
CO2: Analyze and interpret the results using tables and figures for visualization.
CO3: Compile the problem, solution method and the findings of the project work.
CO4: Develop an extensive and independently written thesis using relevant scientific theories/methods and defend the thesis.

The project work 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 evaluationcommittee with an external examiner.

“The project work/thesis will be considered for awarding Grade ‘S’ only if a paper, based on the project work is published/accepted for presentation at least in a Scopus indexed conference or a software copyright is granted. However, in exceptional cases, where the student and the guide want to submit a journal/conference publication at a later stage and if the student is able to submit the draft version of the journal/conference paper to the evaluation committee at the time of final presentation of the project work, the student may be considered for awarding ‘S’ grade if the committee finds the work to be excellent and guide ensures the submission of the work for journal/conference publication”

Programme Specific Electives

ME6621E RIGID BODY MECHANICS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Solve rigid body statics problems using equations of equilibrium.
CO2: Perform kinematic and dynamic analyses of a particle.
CO3: Perform kinematic analysis of rigid bodies.
CO4: Calculate the second moments and products of inertia of rigid bodies.
CO5: Perform dynamic analysis of rigid bodies using various methods.

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.

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.

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 and balancing.

Dynamics of general rigid-body motion

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

ME6622E BEHAVIOUR AND SELECTION OF MATERIALS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Understand the basics and significance of material selection in design.
CO2: Select materials based elastic properties.
CO3: Select materials based on properties like plasticity, fracture and dynamic behaviour of materials.
CO4: Select materials based on thermal, chemical and electromagnetic properties of materials.
CO5: Understand advanced materials and advanced topics in material selection.

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

Material selection based on elastic properties
Elastic moduli – atomic structure and bonding – physical basis of elastic properties – case studies in modulus-limited design.

Material Selection based on other mechanical properties
Plastic behaviour: 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 material selection - Material selection based on fracture toughness, fatigue failure, friction and wear.

Thermal, chemical and electromagnetic properties
Thermal properties – creep and diffusion – case studies in design based on thermal properties – material selection based on chemical properties: oxidation and corrosion – electrical, magnetic and optical properties of materials.

Miscellaneous topics
Special-purpose materials: shape memory materials, energy storage materials, cryogenic materials and materials for space applications – optimization with multiple constraints and objectives – selection of materials and shape – feel and appearance of materials – process selection – materials and environment – final case study.

References:
[1] Ashby, M., F., 2010, *Materials Selection in Mechanical Design,* Butterworth-Heinemann, (2010).
[2] Ashby, M., F., and Shercliff, H., and Cebon, D., 2014, *Materials: Engineering, Science, Processing and Design,* Butterworth-Heinemann.
[3] Ashby, M., F., and Jones, D., R., H., 2011, *Engineering Materials 1: An Introduction to Properties, Applications and Design,* Butterworth-Heinemann.
[4] Tabor, D., 1991 *Gases, Liquids and Solids: and other States of Matter,* Cambridge University Press.
[5] Dieter, G., E., 1988 *Mechanical Metallurgy,* McGraw-Hill.
[6] Dieter, G., E., and Schmidt, L., C., 2012, *Engineering Design,* McGraw-Hill.

ME6623E INDUSTRIAL TRIBOLOGY

Pre-requisites: A working knowledge of Advanced Mechanics of Solids

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes
CO1: Understanding of the fundamentals of tribology and the tribological parameters of all classes of materials.
CO2: Recognize the principles of friction, wear, wear mechanisms, lubrication, lubrication regimes, hydrodynamic lubrication, hydrostatic lubrication, bio-tribology, and micro/ Nano tribology.
CO3: Explore concepts of tribology for the selection of proper materials and lubricants for a given and desired tribological performance and design of machine elements.
CO4: Perform systematic literature review of advancements in tribology and conduct studies to validate results from the available literature.

Surface Topography and Surfaces in Contact, Quantifying surface roughness, Topography of engineering surfaces, Contact between surfaces, Elastic stress fields, Plastic deformation, Deformation of a single asperity, Contact of coated surfaces, Surface energy in elastic contact, Origin of friction, Friction of metals, Friction of ceramics materials, Friction of lamellar solids

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, 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.

Sliding Wear, Wear of metals: adhesive wear; abrasive wear; corrosion and corrosion wear; erosion; surface fatigue and impact wear; measurement of friction and wear, - Mechanisms of the sliding wear of metals, Wear regime maps for metals, Fretting wear of metals, Wear of metals in lubricated contacts. Sliding wear of ceramics and polymers, Design and Selection of

Applications and Case Studies-Materials for Tribological Application, Estimation of wear rates, the system approach, reducing wear by changing the operating variables, Effect of lubrication, Selection of materials and surface engineering methods

References:
[1] Majumdar, B., C., 1986, *Introduction to Tribology of Bearings*. A. H. Wheeler & Company.
[2] Pinkus, O., and Sternlicht, B., 1961, *Theory of Hydrodynamic Lubrication*. McGraw-Hill.
[3] Moore, D., F., 1975, *Principle and Application of Tribology*. Pergamon Press.
[4] Rabinowicz, E., 1995, *Friction and Wear of Materials*. John Wiley & Sons.
[5] Johnson, K., L., 1987, *Contact Mechanics*. Cambridge university press.
[6] Thomas, T., R., 1988, *Rough Surfaces*. World Scientific.

ME6624E DESIGN OF ELECTRO-MECHANICAL SYSTEMS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Model physical systems mathematically using transfer function method, block diagram reduction technique and state space method.
CO2: Identify actuators & sensors for an EMS through case studies.
CO3: Select electrical drives and understand methodology for signal conditioning and data acquisition.
CO4: Design control strategies such as Proportional, Integral, Derivative and PID controllers for an EMS.

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.

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.

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] Bolton, W., 2019, *Mechatronics, Electronic Control Systems in Mechanical and Electrical Engineering*, Pearson.
[2] Necsulescu, D., S., 202, *Mechatronics*, Pearson.
[3] Drof, R., C., and Bishop, R., H., 2017, *Modern Control Systems*, Pearson.
[4] Kant, K., 2011, *Computer-Based Industrial Control*, Prentice Hall of India.
[5] HMT Limited, 2017, *Mechatronics*, McGraw-Hill Education.
[6] Taub, H., and Schilling, D., 2017, *Digital Integrated Electronics*, McGraw Hill Education.
[7] Lyshevski, S., E., 2008, *Electromechanical Systems and D*evices, Taylor & Francis Group.
[8] Clarence, W., S., 2004, *Mechatronics: an Integrated Approach*, CRC Press.

ME6625E NONLINEAR DYNAMICS

Prerequisite: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course outcomes:

CO1: Comprehend and analyze the dynamics of nonlinear continuous-time dynamical systems.
CO2: Analyze chaotic systems.
CO3: Analyze nonlinear systems, through discrete time systems or maps.
CO4: Understand the notion of fractal and fractal dimensions
CO5: Familiarize and develop computer programmes in nonlinear dynamical systems

One-Dimensional Flows

Flows on the Line: A Geometric Way of Thinking, Fixed Points and Stability, Linear Stability Analysis, Existence and Uniqueness; Potentials, Population Growth; Saddle-Node, Transcritical, Pitchfork Bifurcations; Imperfect Bifurcations and Catastrophes

Two-Dimensional Flows

Linear Systems: Definitions and Examples; Classification of Linear Systems; Analysis of Different Linear Systems; Phase Plane: Phase Portraits, Fixed Points and Linearization; Conservative Systems, Reversible Systems; Phase Diagram for the Pendulum Equation; Index Theory; Limit Cycles: Examples, Ruling Out Closed Orbits, Poincare-Bendixson Theorem; Different Systems Showing Limit Cycles Bifurcations: Saddle-Node, Transcritical and Pitchfork Bifurcations; Hopf Bifurcations; Examples on Different Types of Bifurcations

Tools to Identify and Analyze Motions

Introduction to Quasiperiodic and Chaotic Motions; Fourier Spectra; Poincare' sections and maps; Lyapunov Exponents; Numerical Integration; Parametric Continuation; Harmonic Balance; Averaging Method; Perturbation Methods

Discrete Time Systems and Fractals

One dimensional map; Fixed points of maps – stability, cobweb diagram, stability of periodic points, basin of attraction; Logistic map – Periodic orbits, stability, chaos, bifurcation diagram; P3 window, intermittency; Tent map, Shift map; Two-dimensional maps; Henon Map; Fractal and Dynamical Systems: Cantor Set, Koch Curve, etc.; Fractal dimensions; Introduction to Julia set, Mandelbrot set and iterative function system (IFS); Computer based exercises in discrete time dynamical systems.

References

[1] Strogatz, S., H., 2015, *Nonlinear Dynamics and Chaos*, CRC Press.
[2] Jordan, D., and Smith, P., 2007, *Nonlinear Ordinary Differential Equations*, OUP Oxford.
[3] Nayfeh, A., H., and Balachandran, B., 2008, *Applied Nonlinear Dynamics: Analytical, Computational, and Experimental Methods*, John Wiley & Sons.
[4] Thomson, J., M., T., and Stewart, H., B., 2002, *Nonlinear Dynamics and Chaos*, John Wiley & Sons.
[5] Moon, F., C., 2008, *Chaotic and Fractal dynamics*, John Wiley & Sons.
[6] Lynch, S., 2009, *Dynamical System with Applications using MAPLE,* Springer.
[7] Mallik, A., K., and Bhattacharjee J., K., 2005, *Stability Problems in Applied Mechanics*, Alpha Science Int'l Ltd.

ME6626E PRODUCT DESIGN

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Session: 39

Course Outcomes:

CO1: Use the Product Design and Development Process from ideation stage to product through concepts.
CO2: Apply creative process techniques in synthesizing information, problem-solving and critical thinking.
CO3: Demonstrate, apply, explain, and recognize basic engineering, mechanical, and technical principles used in the Product Development
CO4: Apply and familiarize with the basic family of materials, processes and practices including sustainable materials and manufacturing processes.

Introduction, Development Processes and Organizations, Relation between type of design and S-curve, Kolb's Model of Product Development, Opportunity Identification, Product Planning, Identifying Customer Needs, Product Specifications, The Product Development Process: "IDEO", Customer Preferences: Conjoint Analysis, Benchmarking, distinctions between stage-gate model and spiral model, FAST and SOP methods of developing product functions, The QFD Process,

Concept Generation, TRIZ, Concept Selection, Concept Testing, Product Architecture, Industrial Design, Robust Design, Design for manufacturing and Assembly Methods of designing for manufacturing and assembly, Design for Environment, Methods of designing environmentally conscious products, Human factors in design Human anthropometric, ergonomic, psychological, physiological considerations in design

Patents and Intellectual Property, Service Design, Design for sustainability, Product Development Economics, Managing Projects, Design of a specific product (Project)

References:

[1] Ulrich, K., T., and Eppinger, S., D., 2004, *Product Design and Development*, McGraw-Hill International Edn.

[2] Dieter, 1991, *Engineering Design*, II Edition, McGraw Hill

[3] Ullman, D., G., 2010, *The Mechanical Design Process,* McGraw-Hill Companies

[4] Shigley, J., E., and Mischeke, C., R., and RichardG., B., 2004, *Mechanical Engineering Design*, TMH Publishers.

[5] Michael G., L., Scott, S., and Abbie G., 2015, *Design Thinking*, John Wiley & Sons, Inc.

[6] Benjamin, W., N., and Draper, A., B., 1974, *Product Design and Process Engineering*, McGraw Hill Book Co.

ME6627E DESIGN OF PRESSURE VESSELS AND PIPING

Prerequisite: A working knowledge of mechanics of solids

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course outcomes:

CO1: Determine stresses and the support members in pressure vessels
CO2: Explore requirements applicable to materials, flanges, supports, design conditions of pressure vessels.
CO3: Learn the requirements of the ASME Boiler and Pressure Vessel Code (BPVC)
CO4: Design of Pressurized fluid piping

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.

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.

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

ME6628E PLASTICITY: FUNDAMENTALS AND COMPUTATIONAL METHODS

Pre-requisites: A working knowledge of Theory of Elasticity

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Understand the basic concepts of micro-plasticity and continuum theory of plasticity.
CO2: Formulate general problems in plasticity based on fundamental concepts.
CO3: Analyze problems in plasticity using finite element method and other computational methods.

Fundamentals
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 Theory of Plasticity: experimental observations, true stress-true strain relations, effect of work hardening, empirical stress-strain relationships.

Microstructural mechanisms of plasticity
Review of crystal structures – ideal strength and defects in crystals – elements of dislocation theory – other mechanisms of plasticity like twinning, grain boundary sliding and vacancy diffusion – plasticity of single crystals and polycrystals.

Continuum plasticity
Yield criterion: fundamentals, stress space representation, Tresca and von Mises criterion, experimental observations, yield surface for work hardening materials – stress-strain relations in the plastic range: Prandtl-Reuss and Levy-Mises relations, stress-strain relations for strain-hardening materials, derivation of elasto-plastic constitutive tensor for isotropic hardening and kinematic hardening – unloading criterion – plastic instability.

Computational methods in plasticity
Atomistic (molecular dynamics), mesoscale (dislocation dynamics) and continuum (finite element) methods – basics of finite element method – nonlinear analysis: convergence and tolerance – return-mapping algorithm – implementation of stress-strain relations: perfectly plastic, isotropic hardening and kinematic hardening materials – unloading detection – introduction to multiscale methods.

References:

[1] Sadd, M., H., 2014, *Elasticity: Theory, Applications and Numerics*, Academic Press.
[2] Chakrabarty, J., 2011,*Theory of Plasticity*, Butterworth-Heinemann.
[3] Johnson,W., and Mellor, P., B., 1987, *Engineering Plasticity,* McGraw-Hill.
[4] Hill, R., 2009, *The Mathematical Theory of Plasticity*, Oxford University Press.
[5] Dieter, G., E., 1988, *Mechanical Metallurgy*, MGraw-Hill Book Company.
[6] Dunne, F., and Petrinic, N., 2005, *Introduction to Computational Plasticity*, Oxford University Press.
[7] Borst, R., De., Crisfield, M., A., Remmers, J., J., C., and Verhoosel, C., V., 2012, *Non-linear Finite Element Analysis of Solids and Structures,* Wiley.
[8] Neto, E., A., D., Peric D., and Owen D., R., J., 2008, *Computational Methods for Plasticity: Theory and applications*. Wiley.
[9] Pippan, R., and Gumbsch, P., 2010, *Multiscale Modeling of Plasticity and Fracture by means of Dislocation Mechanics*, Springer.

ME6629E CONTINUUM MECHANICS

Pre-requisites: Working knowledge Theory of Elasticity

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Perform computations and derivations using tensor algebra and calculus.

CO2: Conduct kinematic analysis of a continuous object using various measures of strain.

CO3: Perform kinetic analysis using the fundamental principles and various measures of stress.

CO4: Use the constitutive relations for analyzing the continuous objects.

Tensor algebra and calculus

Continuum hypothesis and concept of field – scalar, vectors and second order tensors – tensor formalism and notational conventions – vector algebra – algebra of matrices and tensors – vector calculus – tensor transformation – tensor calculus: time derivative, gradient operator, directional derivative.

Kinematics of a continuum

Description of motion – analysis of deformation – strain measures – rotation and strain tensors for infinitesimal deformation – Lagrangian and Eulerian measures of strain – velocity gradient and vorticity tensors – compatibility conditions – rigid body motion and objectivity – polar decomposition theorem.

Stress Measures

Cauchy stress tensor and its properties – Piola-Kirchhoff stress tensors – equilibrium equations for small deformation – objectivity of stress tensors.

Balance laws and general principles

Conservation of mass – balance of linear and angular momentum – thermodynamic principles: balance of energy and entropy inequality – material and spatial descriptions of the balance laws and general principles.

Constitutive Relationships

The elastic solid – linear elasticity: isotropic and anisotropic materials – nonlinear elastic materials – Newtonian fluids – generalized Newtonian fluids.

References:

[1] Reddy J., N., 2016, *An Introduction to Continuum Mechanics*, Cambridge University Press.

[2] Lai, W., M., Rubin, D., and Krempl, E., 2015, *Introduction to Continuum Mechanics,* Butterworth-Heinemenn.

[3] Chandrasekharaiah, D., S., and Debnath, L.,1994, *Continuum Mechanics,* Academic Press.

ME6330E EXPERIMENTAL STRESS ANALYSIS

Pre-requisites: Knowledge of Mechanics of Solids fundamentals

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Understand analytical methods to solve elasticity problems
CO2: measure the strains in a body using experimental methods
CO3: understand brittle coating techniques and methods for brittle coating analysis
CO4: measure the stresses and strains in body using photo-elastic methods

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.

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.

Two dimensional photo elasticity, Photo elastic materials, Concept of light, photoelastic effects, stress optic law, Transmission photoelasticity, 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 photoelastic materials, Compensation and separation techniques, Introduction to three dimensional photo elasticity, stress freezing.

References:

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

ME6631E FRACTURE MECHANICS AND FATIGUE

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Familiarize with concepts of fracture mechanics and fatigue
CO2: Estimate the safety of the components using LEFM concepts
CO3: Estimate the safety of the components using EPFM concepts
CO4: Estimate the safety of the components loaded with fatigue loads

Linear Elastic Fracture Mechanics
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,

Elasto-Plastic Fracture Mechanics
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

Fatigue analysis and design
Design of components in fatigue loading, infinite life approach- S-N Curve, Factors affecting endurance limit, Theories of failure in fatigue
Finite Life approach- Law cycle fatigue and high cycle approach, Coffin-Manson rule, Cyclic stress strain curve. Basquin Equation
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. Anderson, T. L., 2017, *Fracture mechanics: fundamentals and applications*, CRC press.
2. Ewalds, H.L., and Wanhill, R.J.H., 1984, *Fracture mechanics*, Edward Arnold.
3. Broek, D., 2012, *Elementary engineering fracture mechanics*, Springer Science and Business Media.
4. Kumar, P., 2009, *Elements of fracture mechanics*, McGraw-Hill Education LLC.
5. Stephens, R. I., and Fatemi, A., Stephens, R. R., and Fuchs, H. O., *2000, Metal fatigue in engineering*, 2nd ed., John Wiley and Sons.
6. Hellan, K., 1984, *Introduction to fracture mechanics*, McGraw-Hill Inc.

ME6632E ROBOTICS

Pre-requisites: Engineering Mechanics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the subsystems, types, applications and history of robots.
CO2: Model serial robotic manipulators kinematically using geometrical and analytical methods.
CO3: Model serial robotic manipulators statically and dynamically.
CO4: Design the trajectory for robot applications.
CO5: Describe manipulator control system and schemes.

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.

Introduction to serial robotic manipulator kinematics and statics: Denavit-Hartenberg (DH) notation, forward and inverse kinematic analysis, solvability, algebraic vs. geometric, examples, case studies of modeling on real robot mechanism; Piper's 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.

Serial Robotic manipulator dynamics: acceleration of a rigid body, mass distribution, iterative Newton-Euler dynamic formulation; Lagrange-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 system, nonlinear and time varying systems, multi-input and multi-output control systems, PID control scheme, force control of manipulators.

References:
1. Craig, J. J., 2022, *Introduction to Robotics: Mechanics and Control*, Pearson Education.
2. Mittal, R. K., and Nagarath, I. J., 2017, *Robotics and Control*, McGraw Hill Education.
3. Niku, S. B., 2010, *Introduction to Robotics: Analysis, Control, Applications*. Prentice Hall India.
4. Spong, M. W., and Vidyasagar, M., 1989, *Robot Dynamics and Control*, John Wiley & Sons.
5. Fu, K. S., Gonzales, R. C., and Lee, C. S. G., 2017, *Robotics: Control, Sensing, Vision and Intelligence*, McGraw Hill Education.
6. Paul, R. P., 1981, *Robot Manipulators: Mathematics, Programming, and Control.* The MIT Press.
7. Schilling, R. J., 1996, *Fundamentals of Robotics: Analysis and Control*, Prentice Hall of India.

ME6633E MECHATRONICS SYSTEMS AND FLUID POWER AUTOMATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain various key elements or subsystems in mechatronics.
CO2: Identify sensors, actuators and data acquisition systems for a given mechatronics system.
CO2: Develop PLC programming for automated systems and analyze control part.
CO4: Identify the drives, mechanisms and other components of automated systems.
CO5: Design industrial low cost automation circuits using fluid power components.

Introduction to mechatronics system: 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, fibre optic sensors - magnetostrictive transducer, selection of sensors, microsensors in mechatronics.

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**.**

Drives and mechanisms of an automated system: drives: stepper motors, servo drives; balls screws, linear motion bearings, cams, systems controlled by camshafts, electronic cams, indexing mechanisms, tool magazines, and transfer systems.
Hydraulic and Pneumatic system hydraulic 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. Shetty, D., and Kolk, R. A., 2010, *Mechatronics System Design*, Cl-Engineering.
2. Groover, M. P., 2016, *Automation, Production Systems, and Computer Integrated Manufacturing*, Pearson Education.
3. Bolton, W., 2019, *Mechatronics, Electronic Control Systems in Mechanical and Electrical Engineering*, Pearson.
4. HMT Limited, 2017, *Mechatronics*, McGraw-Hill Education.
5. Singh, B. P., 2008, *Microprocessors and Microcontrollers*, New Age International.
6. Petruzella, F. D., 2019, *Programmable Logic Controllers*, McGraw-Hill.
7. Blackburn, J. F., and Reethof, G., and Shearer, J. L., *1960, Fluid Power Control*, The MIT Press.
8. Esposito, A., 2013, *Fluid Power with Applications*, Pearson Education.
9. Boucher, T. O., 2012, *Computer Automation in Manufacturing: An Introduction*, Springer Science & Business Media.

ME6634E ROTOR DYNAMICS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Recall and describe the fundamental principles underlying the dynamics of rotor systems for the free lateral response.
CO2: Apply and solve rotor dynamics problems by constructing models and analyzing the effects of anisotropic and flexible supports.
CO3: Analyze and evaluate the natural frequencies, mode shapes, and their significance concerning potential resonances and critical speeds in rotor systems.
CO4: Assess and demonstrate the ability to identify instabilities in rotors

Introduction to rotor dynamics- simple case transverse vibrations
Review of vibrations, multi degree of freedom- Introduction to rotor dynamics, SDOF model for rotor, Jeffcott rotor model, two degree of freedom model- a rigid rotor mounted on simple anisotropic springs as bearings- rigid rotor on complex anisotropic bearings

Gyroscopic effects on rotors
Introduction to gyroscopic effects, splitting of natural frequencies, critical speed of cantilever rotors with thin disc and long stick- gyroscopic effects using dynamic approach

Torsional vibrations of rotor system
Torsional vibration of shafts, critical speeds, simple shafts with several disks-Transfer matrix methods for flexible rotor torsional vibrations- FEM methods for torsional vibration analysis

Transverse vibration of multiple mass rotor system
Transfer matrix approach of multi mass rotor system, elastic and massless shaft- continuous system modeling of multi mass rotor system using Euler-Bernoulli beam theory- FEM method of Transverse vibrations of flexible rotor system-incorporation of gyroscopic effects on stiffness and damping of bearings in FEM formulations

Instabilities and balancing of rotors
Rotor dynamic coefficients for simple hydrodynamic and rolling bearings- stiffness and damping coefficients of hydrodynamic bearings- sources of instability in rotors, Routh's criteria for stability of fluid film bearings with linearized stiffness and damping properties, simple models for instability due to internal damping and shaft asymmetry, steam whirl and seal induced instabilities- Introduction to rigid rotor balancing- static and dynamic balancing of rotors, conventional cradle balancing method, modern influence coefficient method

References:

1. Tiwari, R., 2017, *Rotor systems: analysis and identification*, CRC press.
2. Genta, G., 2005, *Dynamics of rotating systems,* Springer Science and Business Media.
3. Rao, J. S., 1996, *Rotor Dynamics,* New Age International.
4. Friswell, M. I., Penny, J. E. T., Garvey, S. D., and Lees, A. W., 2010, *Dynamics of Rotating Machines*. Cambridge University Press.
5. Vance, J. M., and Zeidan, F. Y., and Murphy, B. G., 2010, *Machinery vibration and rotordynamics*. John Wiley and Sons.

ME6635E ANALYTICAL AND NONLINEAR DYNAMICS

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course outcomes:
CO1: Formulate and solve problems in analytical mechanics
CO2: Ability to analyze nonlinear systems
CO3: Analyze discrete time nonlinear dynamic systems
CO4: Use basic computational tools in nonlinear dynamics

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.

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

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. Meirovitch, L., 1997, *Principles and techniques of vibrations*, Prentice Hall New Jersey.
2. Greenwood, D. T., 1988, *Principles of dynamics*, Prentice-Hall Englewood Cliffs, NJ.
3. Strogatz, S. *Nonlinear dynamics and chaos*. Perseus books publishing, LLC, (2000)
4. Lynch, S., 2009, *Dynamical systems with applications using MapleTM*, Springer Science and Business Media.
5. Nayfeh, A. H., and Balachandran, B., 2008, *Applied nonlinear dynamics: analytical, computational, and experimental methods*, John Wiley and Sons.
6. Moon, F. C., 2008, *Chaotic and fractal dynamics: introduction for applied scientists and engineers*, John Wiley and Sons.
7. Greenwood, D. T., 2006, *Advanced dynamics*, Cambridge University Press.
8. Strogatz, S. H., 2000, *Nonlinear Dynamics and Chaos*, Perseus Books Publishing, LLC.
9. Thompson, J. M. T., and Stewart, H. B., 2001, *Nonlinear dynamics and chaos*, John Wiley & Sons.

ME6336E COMPUTER GRAPHICS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Apply fundamental knowledge in mathematics for generating and transforming graphic entities using computers.

CO2: Model curves and surfaces mathematically.

CO3: Create computer programs for displaying and manipulating curves, surfaces and solids using computers.

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.

Plane curves; nonparametric and parametric curves: Space curves; Representation of space curves; cubic spline; Bezier curves; B-spline curves; NURBS.

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. Rogers, D. F., and Adams, J. A., 2009, *Mathematical elements for computer graphics*, Tata McGraw-Hill.
2. Rogers, D. F., 1986, *Procedural elements for computer graphics*, McGraw-Hill Inc.
3. Hearn, D., 2007, *Computer graphics*, 2nd ed., Prentice Hall of India Private Limited.
4. Mortenson, M. E., 1997, *Geometric modeling*, John Wiley and Sons Inc.
5. Foley, J. D., Dam, A. V., Feiner, S. K., and John, F. H., 1995, *Computer graphics: Principles and practice in C*, Addison-Wesley Professional.

ME6637E PRINCIPLES OF VIBRATION CONTROL

Prerequisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain the vibration response of simple systems
CO2: Apply passive vibration control by structural design and use of viscoelastic material
CO4: Analyze and design dynamic vibration absorbers and isolators for vibration attenuation
CO5: Apply active feedback for vibration control

Overview of Vibration
Quantitative Description of Vibration: Undamped and Damped, Unforced and Forced, SDOF, MDOF systems

Vibration Reduction at the Source
Balancing of Rotors, Flow Induced Vibration, Detuning and Decoupling

Vibration Control by Structural Design
Damping Models and Measures, Origin of Structural Damping, Damping-Stress Relationship, Selection Criteria for Linear Hysteretic Materials, Combined Fatigue-Strength Damping Criteria

Viscoelastic Materials for Vibration Damping
Standard Linear Solid - constitutive models, Stress-strain relationship, Complex Modulus, Frequency temperature dependence of complex modulus, Free Layer Damping, Constrained Layer Damping

Dynamic Vibration Absorbers
Introduction, Dynamic Vibration Neutralizers, Self-tuned Pendulum Neutralizer, Optimum Design of Damped Absorbers, Auxiliary Mass with Damper, Absorbers attached to Continuous Systems, Applications

Vibration Isolators
Introduction, Isolators with Complex Stiffness, Isolators with Coulomb Damping, Suspension systems, Applications of Isolators

Active Vibration Control
Review of control theory; Closed Loop Control, Transfer Function, Stability, Feedback Vibration Control

Advanced Topics
Piezoelectric Transducer, MR damper, Shape memory alloy, Energy Harvesting System

References:

[1] Mallik, A. K., and Chatterjee, S., 2014, *Principles of passive and active vibration control*. East West Press.
[2] Den, H., Jacob, P., 1985, *Mechanical vibrations*. Courier Corporation.
[3] Meirovitch, L., 1991, *Dynamics and control of structures*. John Wiley and Sons.
[4] Preumont, A., 2018, *Vibration control of active structures: an introduction*. Springer.
[5] Inman, D. J., 2017, *Vibration with control*. John Wiley and Sons.
[6] Moheimani, S. O. R., and Fleming, A. J., 2016, *Piezoelectric Translators for Vibration Control and Damping*. Springer

ME6638E MULTIBODY DYNAMICS AND APPLICATIONS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Apply knowledge to derive the kinematic constraints of standard joints such as revolute, prismatic, spherical, and cylindrical joints.
CO2: Analyze and evaluate the kinematic and dynamic behavior of open and closed chain-connected bodies using appropriate techniques.
CO3: Evaluate and integrate various formulations used to derive equations of motion for constrained dynamical systems.
CO4: Demonstrate proficiency in coding multibody dynamic simulations and utilize commercial multibody packages effectively for real-world applications

Two-dimensional computational kinematics
Introduction to multibody systems- the concept of reference frames- the concept of degrees of freedom-solution techniques for solving non-linear algebraic equations- Newton Raphson and Quasi-Newton method- Kinematics of rigid bodies-computational methods in kinematics- Formulation of driving and joint constraints

Two-dimensional computational dynamics
Constrained dynamics and forms of dynamic equations- Embedding technique and Augmented formulation-Virtual work and Lagrangian dynamics- kinematic constraints and coordinate partitioning- Constrained dynamics equations- forward and inverse dynamics- Numerical solution to constrained dynamic equations

Three-dimensional constrained kinematics and dynamics
The general motion of a rigid body, three-dimensional rotations- Euler angles- Euler parameters usage and singularity-free representation- Formulation of spatial joint constraints- constrained dynamic equations and solution procedures - introduction to recursive methods for the serial multibody system.

References:

[1] Shabana, A. A., 2009, *Computational dynamics*. John Wiley and Sons.
[2] Nikravesh, P. E., 1998, *Computer-aided analysis of mechanical systems*. Prentice-Hall, Inc.
[3] Nikravesh, P. E., 2018, *Planar Multibody Dynamics: Formulation, Programming with MATLAB, and Applications*. CRC press.
Chaudhary, H., and Saha, S. K., 2008, *Dynamics and balancing of multibody systems*. Springer Science and Business Media.
[4] Haug, E. J., 1989, *Computer aided kinematics and dynamics of mechanical systems*. Allyn and Bacon Boston.
[5] Featherstone, R., 2014, *Rigid body dynamics algorithms*. Springer.

ME6639E THEORY OF MECHANISMS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Perform kinematic analysis of complex planar mechanisms by graphical and analytical methods
CO2: Synthesize mechanisms by graphical and analytical methods.
CO2: Learn path curvature theory and applications of Euler-Savary equation.
CO3: Perform kinematic analysis of spatial mechanisms.
CO4: Design and analyze compliant mechanisms.

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.

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.

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] Mallik, A. K., 2021, *Kinematic analysis and synthesis of mechanisms*. CRC Press.
[2] Sandor, G. N., and Erdman, A. G., 1984, *Advanced mechanism design v. 2: Analysis and synthesis*. Prentice-Hall.
[3] Uicker, J. J., Pennock, G. R., Shigley, J. E., and McCarthy, J. M., 2003, *Theory of machines and mechanisms*. Oxford University Press, New York.
[4] Norton, R. L., 2008, *Design of machinery: an introduction to the synthesis and analysis of mechanisms and machines*. McGraw-Hill/Higher Education.
[5] Ghosh, A., and Mallik, A. K., 2014, *Theory of mechanisms and machines*. Affiliated East-West Press Private Limited.
[6] Howell, L. L., 2001, *Compliant mechanisms*. John Wiley & Sons.

M6640E GEAR DESIGN

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Familiarize the gear terminologies and standards
CO2: Conduct the kinematic analysis and force analysis of the gears
CO3: Design standard gear trains to transmit power
CO4: Design Asymmetric gear trains to transmit power.

Spur gear Design
Fundamentals of toothed gearing - Principles of transmission and conjugate action of spur gears, Characteristics of involute and cycloidal gears, Gear train analysis-simple, compound, planetary-Basic rack form, Characteristics of corrected gears, peaking, tooth thickness of corrected gears at the pitch circle. Working pressure angle, Types of corrected gears, Topping, backlash, distribution of correction factors. Force analysis on spur gears, Two cylindrical and elliptical bodies in contact, Design of spur gears -Lewis tooth form factor, stress correction factor, Buckingham's dynamic load, design of spur gear for bending, contact strength and surface wear.

Design of other types of gears
Helical gear design: Helical gear terminology, Virtual number of teeth, Contact ratio of helical gear, Force analysis on helical gears, Design of helical gear-strength calculation of helical gears, Crossed helical gear, Herringbone gears,
Bevel gear design: Bevel gear terminology, Force analysis on bevel gears, Bending and contact stress calculations, Efficiency of the bevel gear.
Worm and Worm gear design: Types of worms, basic parameters of worm and worm wheel, Force analysis of worm drive, Bending and contact stresses calculations, Effect of heat generation, Efficiency of the worm drive.

Design of asymmetric spur gear
Gear tooth profiles – involute and trochoidal tooth profiles, Rack cutter tip radius for asymmetric rack cutter, Asymmetric gear tooth profile generation –Trochoids and involute tooth profiles generation using full round rack cutter, Load angle, Bending moment arm, critical tooth thickness, radius of curvature at critical fillet, Tooth form and stress correction factors, Bending and contact strength, Wear and efficiency evaluation of asymmetric spur gear- Archard wear equation for calculating wear, Power losses – sliding and rolling power losses.

Reference Books

[1] Buckingham, E., 1988, *Analytical mechanics of gears*. Courier Corporation.
[2] Budynas, R. G., and Nisbett, J. K., 2011, *Shigley's mechanical engineering design*. McGraw-Hill New York.
[3] Shigley, J. E., and Mischke, C. R., 2006, *Mechanical Engineering Design (in SI Units)*. Tata MacGrow Hill.
[4] Radzevich, S. P., 2016, *Dudley's handbook of practical gear design and manufacture*. CRC press.
[5] Kapelevich, A. L., 2021, *Direct gear design*. CRC Press.
[6] Kapelevich, A. L., 2018, *Asymmetric gearing*. CRC Press.
[7] Maitra, G. M., 1994, Handbook of gear design. Tata McGraw-Hill Education

ME6641E DATA DRIVEN TECHNIQUES FOR MECHANICAL ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze signals and systems in both the time and frequency domains and implement signal processing algorithms using software tools like MATLAB or programming languages like Python.
CO2: Perform SVD calculations and apply SVD-based algorithms to evaluate and interpret the results obtained from SVD-based techniques and make informed decisions based on the analysis.
CO3: Apply parametric identification techniques to analyze experimental data and model practical systems.
CO4: Apply the DMD algorithm to time-series data to extract important features, modes, and trends and interpret them in the context of the underlying system dynamics.
CO5: Apply various machine learning models and algorithms specifically designed for signal analysis.

Signal Processing

Introduction to the course, Signals and Systems; Classification of Signals; Discrete Time Signals and Systems; Classification of Discrete Time Systems; Correlation; Discrete Fourier Transform and Computation; Application of DFT; Fast Fourier Transform (FFT); Design of Digital Filters, Filter Types; Interpolation; Curve Fitting; Signal Processing Software Tools: Introduction to Matlab/Python; Signal Processing Software Tools: Signal Processing Libraries and Functions.

Singular Value Decomposition (SVD)

Overview; Matrix Approximation; Mathematical Properties and Approximations; Pseudo-Inverse, Least-Squares, and Regression; Principle Component Analysis.

Parametric Identification

Difference with Non-Parametric Identification; Important Techniques; Least Square Based Methods; Experimental Aspects: Experimental Schemes; Experimental Signal Processing. Sparse Identification of Nonlinear Dynamics (SINDy): Mathematical Formulation; Algorithm and Example Code*.

Dynamic Mode Decomposition

Overview, Formulating the DMD Architecture; The DMD Algorithm; Example Code and Decomposition; Limitations of the DMD Methods; Modal analysis and identification of dominant frequencies and vibration modes; Noise reduction and separation of signal components.

Machine Learning for Signal Analysis

Introduction to machine learning algorithms for signal processing; Supervised Versus Unsupervised Learning; Unsupervised Learning Techniques; Feature Extraction and Selection; Classification Trees and Random Forest Applications* of machine learning in signal processing; Example Codes*.

*** Applications using MATLAB/MAPLE/MATHEMATICA/Any Other Software**

References:

[1] Brunton, S. L., and Kutz, J. N., 2022, *Data-driven science and engineering: Machine learning, dynamical systems, and control*. Cambridge University Press.
[2] Kutz, J. N., Brunton, S. L., Brunton, B. W., and Proctor, J. L., 2016, *Dynamic mode decomposition: data-driven modeling of complex systems*. SIAM.
[3] Proakis, J. G., 2007, *Digital signal processing: principles, algorithms, and applications*. Pearson Education India.
[4] Poularikas, A. D., 2017, *Understanding digital signal processing with MATLAB and solutions*. CRC Press.
[5] Sudeep, T., Anand, N., and Rudra, R., 2022, *Machine Learning in Signal Processing Applications, Challenges, and the Road Ahead*. CRC press.

ME6642E VIBRATION OF CONTINUOUS SYSTEM

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Understand the fundamental concept of vibration of discrete and continuous system.
CO2: Demonstrate how to properly apply the mechanical energy equation to a variety of physical systems like rod, string, beam etc.
CO3: Derive equations of motion for one-dimensional and two dimensional vibrations, and solve problems of free and forced vibrations.
CO4: Analyze and solve problems involving vibrations of the physical systems having one and more than one degrees of freedom.
CO5: Identify the modes of a system and compute its natural frequencies.

Review of mechanical vibration, vibration of single degree freedom system: free and forced vibration, response to harmonic excitation, support excitation, vibration isolation, transmissibility, vibration of two-degree freedom system: Free vibration, matrix formulation, force vibration, Vibration of multi degree freedom system: matrix formulation, eigen value problem, normal modes and their properties. Continuous system: introduction to continuous system, principle of superposition, Hamilton’s principle and Euler Lagrange equation.

Vibration of string and bar: transverse dynamics of string, longitudinal dynamics of bar– Newtonian and variational formulation, free vibration problem – Bernoulli’s solution, modal analysis, initial value problem, force vibration analysis.
One dimensional wave equation: D’Alembert’s solution of the wave equation, Harmonic waves and wave impedance, Energetics of wave motion, scattering of waves, application of wave equation: impulsive start of a bar, axial collision of bar, axially translating string.

Vibration of beam: Euler Bernoulli beam, Equation of motion – Newtonian and variational formulation, various boundary conditions of beam, free vibration problem – modal analysis, initial value problem, force vibration analysis, damped vibration of beam,
Vibration of plate: Newtonian formulation, vibration of rectangular plate - Free vibrations, Orthogonality of plate eigenfunctions, Forced vibrations.

References:

[1] Meirovitch, L., 1986, *Elements of vibration analysis*, 2nd ed., McGraw Hill Education India.
[2] Meirovitch, L., 2010, *Methods of analytical dynamics*. Courier Corporation.
[3] Rao, S. S., 2019, *Vibration of continuous systems*. John Wiley and Sons.
[4] Hagedorn, P., and DasGupta, A., 2007, *Vibrations and waves in continuous mechanical systems*. John Wiley and Sons.
[5] Graff, K. F., 2012, *Wave motion in elastic solids*. Courier Corporation.
[6] Brekhovskikh, L. M., and Goncharov, V., 2012, *Mechanics of continua and wave dynamics*. Springer Science and Business Media.

ME6643E APPLIED FINITE ELEMENT ANALYSIS

Pre-requisites: NIL

Total Sessions: 52

L	T	P	O	C
2	0	2	5	3

Course Outcomes:
CO1: Describe the significance of finite element analysis
CO2: Select appropriate elements and meshing for an analysis
CO3: Model the material behaviour using finite element analysis and apply the appropriate boundary conditions
CO4: Conduct various analyses using FEA
CO5: Read the results from contour plots

Brief review of different numerical methods- Theoretical Finite Element analysis- Software based FEM- Applications of FEM- Various types of analyses using FEM

Elements: Library of elements- Element types-Degrees of freedom of elements-Element selection criteria-shear locking-hourglassing, Meshing: Selection of element size- Meshing of critical regions- mesh refinement-convergence study- Mesh transitions- Rules of 1D,2D and 3D meshing

Material modeling- setting your units- Isotropic, Orthotropic, Anisotropic material, Boundary conditions- Types-properly defining boundary conditions- rigid body elements and multipoint constraints.

Various static analyses: Linear static analysis-characteristics of a linear analysis- Nonlinear analysis- Geometric nonlinearity- material nonlinearity- boundary nonlinearity- choosing the right elements- general recommendations- common mistakes- contact analysis
Dynamic analysis- Free vibration- Forced vibration- single DOF- transient response analysis-
Fatigue analysis-various approaches in fatigue analysis- Stress life and strain life approach- Multi- axial approach.

Modeling of manufacturing processes- modeling of welding and additive manufacturing processes- machining processes- various damage criteria

Understanding FEA outputs- standard outputs- post processing- contour plots- performance improvement in computing- parallel computing- system

Exercise for practical sessions

1. Exposure to at least one commercial finite element software with various options available in the software
2. Solution of linear statics problems with exposure of different elements- typical problems in solid mechanics- bar under axial load- Solution of beam bending problems using Euler- Bernoulli's beam theory and Timoshenko beam theory-
3. Meshing of complex geometries
4. Modeling of different types of materials- Modeling of orthotropic and anisotropic model- Kinematic hardening and isotropic hardening- modeling of viscoelastic and hyper elastic models
5. Imposition of rigid body and multipoint constraints
6. Modeling of problems with geometric non linearity and boundary nonlinearity
7. Modeling of dynamic problems
8. Low cycle fatigue analysis
9. Modeling of heat flux and temperature dependent properties in welding and additive manufacturing
10. Modeling of machining process

11. Plot the results from the software- Export the results- Plot the results along a path

References:

[1] Madier, D., 2020, *Practical Finite Element Analysis for Mechanical Engineers*. FEA Academy.

[2] Gokhale, N. S., 2008, *Practical finite element analysis.* Finite to infinite.

[3] Mac B., and Bryan J., 2007, *Practical stress analysis with finite elements*. Glasnevin publishing.

ME6644E INTRODUCTION TO VEHICLE DYNAMICS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	0	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Describe the various static and dynamic forces acting on a vehicle
CO2: Evaluate the effect of various vehicle parameters on the ride and handling of the vehicle.
CO3: Evaluate the various factors affecting the dynamics of two wheelers.

Basics of engineering mechanics and dynamics: Free body diagrams- Newton's laws of motion- law of friction-Rolling friction
Static loads in vehicle: Axle loads in stationary vehicles- Axle loads on gradients
Dynamics Loads in acceleration: Acceleration loads-maximum possible acceleration-traction limited acceleration- Effect of front wheel drive/ rear wheel drive/ all-wheel drive systems.
Dynamic loads during braking: Braking performance- brake distribution between front and rear wheels- wheel lock up- electronics to prevent wheel lock up- Antilock braking systems(ABS)- Electronic Brake Distributions(EBD)
Miscellaneous Loads: Aerodynamic loads- Riding resistance, Power required to cruise at constant speeds.

Suspension systems: Basic suspension systems- independent suspensions-vehicle modeling with single degree of freedom model -Quarter car model - Effect of suspension stiffness on ride and handling. Advanced systems to improve ride and handling- progressive springs and dampers- active and semi active suspension systems
Steering- steering geometry- Caster, Camber, Toe-in, toe-out steady state cornering- understeer and oversteer- all wheel steering systems- study of various steering systems used in modern automobiles
Wheels and tires: - Basic tire nomenclature- Effect of unsprung mass- Effect of moment of inertia, Roll over analysis

Motorcycle dynamics: Modeling of two wheelers- loads on wheels- forces acting on motor cycle
Front wheel/steering Geometry- caster angle, Offset, Trail, Effect of steering geometry on straight line stability and handling.
Motorcycle suspension: Types-telescopic, upside down forks, relative advantages and disadvantages,
Vehicle Frames: Types- single cradle, double cradle, perimeter frame, Trellis frame, monocoque construction-Relative advantages and disadvantages

References:

[1] Gillespie, T., 2021, *Fundamentals of vehicle dynamics*. SAE international.

[2] Wong, J. Y., 2022, *Theory of ground vehicles*. John Wiley and Sons.

[3] Pacejka, H., 2005, *Tire and vehicle dynamics*. Elsevier.

[4] Blundell, M., and Harty, D., 2004, *Multibody systems approach to vehicle dynamics*. Elsevier.

[5] Vittore, C., 2005, *Motorcycle Dynamics*. Lulu.com.

ME6645E MATERIAL SELECTION IN MECHANICAL DESIGN

Prerequisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Familiarise different classes of material and their potential applications
CO2: Familiarise mechanical behaviour of different materials
CO3: Select the materials considering the expected material behaviour
CO4: Select suitable materials for an application based on the objective

Classification of Materials
Historical evolution of engineering materials - Classification of materials - Families of engineering materials and their properties, Iron based materials, Aluminium based materials, Super alloys, Composite materials, Plastics and elastomers, Glass and ceramics, Shape memory alloys, Biocompatible materials - Material designation systems

Behaviour of Materials
Elastic Behaviour -Hooks Law, Anisotropic Behaviour, Viscoelastic Behaviour-Plastic behaviour-Cyclic stress strain behaviour- Failure behaviour, Yielding theories for metals, Failure theories of composites, Basics of fracture mechanics, Creep, Fatigue, High temperature behaviour, Miscellaneous properties-Vibration damping behaviours, Wear resistance, Corrosion resistance, Biocompatibility

Selection of materials
Introduction to Ashby charts- Selection of materials, Derivation of material index, Selection of material based on single objective, Selection of material based on multiple objectives, Material selection with multiple objectives and multiple constraints - Material shape efficiency factor - 4 quadrant methodology for the selection of materials.

References:
[1] Ashby, M. F., 2011, *Materials Selection in Mechanical Design*. Butterworth-Heinemann.
[2] Ashby, M. F., Shercliff, H., and Cebon, D., 2014, *Materials: Engineering, Science, Processing and Design*. Butterworth-Heinemann.
[3] Ashby, M. F., and Jones, D. R. H., 2011, *Engineering Materials* – 1. Butterworth-Heinemann.
[4] Charles, J. A., 2023, *Selection and Use of Engineering materials*. Butterworth-Heinemann.
[5] Calister, W. D., and Balasubramanian, R., 2022, *Material Science and Engineering*. Wiley India Publications.

ME6646E BIO-INSPIRED DESIGN

Prerequisites: NIL

Total hours: 39

L	T	P	O	C
3	0	0	6	3

Course outcomes:

CO1: Introduce students to the successful products that we see in nature and understand the structural features that gave them advantage in their evolution

CO2: Analyse a few selected products in depth to inspire design ideas for strength, surface engineering, actuation, locomotion, etc.

CO3: Apply the learnings to improve engineering products/processes

CO4: Develop designer's skills to observe and adapt nature's designs in engineering

Introduction

Nature walk – a walk around the campus to encourage the observation of natural products around us. Introduction – evolution, adaptation for survival, building blocks, salient features, how the study of nature's products can help engineers, examples.

Mechanical design features

Hierarchical and additive construction, bio-composites, structure & properties of nacre, bones, teeth, trees, bamboo, spider silk, woodpecker, impact resistance, fracture mitigation.
Scaling laws & Constructal law - scaling laws in nature, applications to engineering designs, Constructal law.

Surface engineering & Thermal control

Surface energy, wetting, capillarity, effects of multi-scale roughness, lotus effect, gecko adhesion, mussel adhesion, pitcher plant, drag reduction, synovial joint, anti-fouling surfaces, structural colours.
Thermal control – Heat dissipation/conservation, insulation of fur and feathers, termite mounds, bee hives, endothermy, behavioral adaptations, radiative cooling.

Sensors, Actuators, Locomotion & Navigation

Animal & plant sensors, muscles, water-driven plant movements, snap-action, seed dispersal, mantis shrimp, chameleon, soft actuators, and applications in robotics.
Locomotion & Navigation– energy cost of walking/running, swimming, flight, navigation & migration of fishes, turtles & migratory birds.

Miscellaneous products

Electric eel, fruit impact, particle filtering, soft robotics, etc.

References:

[1] Chen, P-Y, McKittrick, J., and Meyers, M. A., 2012, *Biological materials – functional adaptations and bioinspired designs*, Progress in Material Science, Vol. 57 (8), pp. 1492-1704.

[2] Nepal D., *et al*., 2023, *Hierarchically structured bioinspired nanocomposites*, Nature Mater, 22.

[3] Amorim, L., *et al.*, 2021, *Bioinspired approaches for toughening of fibre reinforced polymer composites*, Materials and Design, 199, 109336.

[4] Li, S., and Wang, K. W., 2017, *Plant-inspired adaptive structures and materials for morphing and actuation – a review*, Bioinspiration & Biomimetics, 12, 011001.

[5] Barthelat, F., Yin, Z., and Buehler, M. J., 2016, *Structure and mechanics of interfaces in biological materials*, Nature Rev Mater, 1, 16007.

[6] Dunlop, J. W. C., and Fratzl, P., 2010, *Biological composites*, Annual Review of Materials Research, 40, pp. 1-24.

[7] Patek, S. N., 2015, *The most powerful movements in biology,* American Scientist, Vol. 103, pp. 330-337.

[8] *Biology Bookshelf*, LibreTexts, UC Davis.

[9] Biewener, A. A., and Patek, S. N., 2018, *Animal locomotion*, Oxford University Press.

[10] *Bio-inspired structures*, MIT Open Courseware.

ME6647E SCIENCE OF CLASSICAL MUSICAL INSTRUMENTS

Prerequisites: Basic physics and materials science

Total lecture sessions: 39

L	T	P	O	C
3	0	0	6	3

Course outcomes:

CO1: Introduce the evolution of classical musical instruments, understand their construction and improvements with materials technology
CO2: Classification of instruments according to *Natya sastra* and Hornbostel-Sachs
CO3: Analyse the acoustics, mechanics, materials and construction of string, percussion and wind instruments
CO4: Apply modern scientific perspectives to a few selected instruments to appreciate the achievements of master craftsmen who created the instruments by trial and error processes

Physics of sound
musical sound, hearing, scales, vibration modes, Chladni patterns.

Classical musical instruments
evolution, classification, subjective and objective evaluation.

Materials for musical instruments
tone wood microstructure and properties, wood treatments, varnish, glue, metallic alloys, string materials, skins, ceramics, characterisation techniques, conservation of instruments.

String instruments
Mersenne's law, inharmonicity, string material constraints, construction of vina, tanpura, sitar, violin, guitar, piano, etc.

Percussion instruments
vibration of membranes, effect of nonuniform density, mridangam, tabla, drums.

Wind instruments
acoustics of air flow in instruments, flute, woodwinds, brasses.

Idiophones
bells, xylophones, ghatam, jal-tarang, lithophones.

References:

[1] Fletcher, N. H., and Rossing, T. D, 1988, *The physics of musical instruments,* Springer.
[2] Rossing, T. D., (ed) 2010, *The science of string instruments*, Springer.
[3] Benade, A. H., 1990, *Fundamentals of musical acoustics*, Dover.
[4] Hartmann, W. M., 2013, *Principles of musical acoustics*, Springer.
[5] Deva, B. C., 1977, *Musical instruments,* National Book Trust.
[6] Kasliwal, S., 2001, *Classical musical instruments*, Roopa & Co.

INSTITUTE ELECTIVES

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: NIL

Total Lecture Sessions: 26

L	T	P	O	C
2	0	0	4	2

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

[1] Kaplan, J. M., Warren, A. C., and Murthy V., 2022, *Patterns of entrepreneurship management.* John Wiley & Sons.
[2] Kuratko, D. F., 2016, *Entrepreneurship: Theory, process, and practic*e. Cengage learning.
[3] Barringer, B. R., 2015, *Entrepreneurship: Successfully launching new ventures*. Pearson Education India.
[4] Shah, R., Gao, Z., and Mittal, H., 2014, *Innovation, Entrepreneurship, and the Economy in the US, China, and India,* Academic Press.
[5] Sundar, K., 2022, *Entrepreneurship Developmen*t, Vijaya Nichkol Imprints, Chennai.

[6] Gordon, E., Natarajan, K., 2017, *Entrepreneurship Development*, Himalya Publishers, Delhi.
[7] Biswas, D., and Dey, C., 2021, *Enterpreneurship Development in India*, Taylor & Francis.

ZZ6002E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: 26

Course Outcomes:
CO1: Explain the basic concepts and types of research.
CO2: Develop research design and techniques of data analysis
CO3: Present research to the scientific community
CO4**:** Develop an understanding of the ethical dimensions of conducting research.

Exploring Research Inquisitiveness
Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis
Literature review :Tools and Techniques - Collection and presentation of data, processing and analysis of data - Descriptive statistics and inferential statistics- Measures of central tendency, dispersion, skewness, asymmetry- Probability distributions – Single population and two population hypothesis Testing - Parametric and non-parametric tests - Design and analysis of experiments: Analysis of Variance (ANOVA),completely randomized design – Measures of relationship: Correlation and regression, simple regression analysis, multiple regression – interpretation of results - Heuristics and simulation

Research writing and Ethics
Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews.
The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey

References:

[1] Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., 2006, *Management Research Methodology, Pearson* Education.
[2] Leedy, P, D., 2018, *Practical Research: Planning and Design*, Pearson.
[3] Kothari, C.R., 2004, *Research Methodology – Methods and Techniques*, New Age International Publishers.
[4] Martin Mike, Schinzinger Roland, 2004, *Ethics in Engineering*, Mc Graw Hill Education.
[5] Sople, Vinod V., 2014, *Managing Intellectual Property-The Strategic Imperative*, EDA Prentice of Hall Pvt. Ltd.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: NIL

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:
CO1: Apply effective communication strategies for different professional and industry needs.
CO2: Collaborate on various writing projects for academic and technical purposes.
CO3: Combine attributes of critical thinking for improving technical documentation.
CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:
[1] Foley, M., and Hall, D., 2018, *Longman advanced learner's grammar, a self-study reference & practice book with answers*, Pearson Education Limited.
[2] Gerson, S. J., and Gerson, S. M., 2009, *Technical writing: Process and product*, Pearson.
[3] Halliday, M. A. K., and Matthiessen, C. M. I. M., 2013, *Hallidays introduction to functional grammar*, Hodder Education.
[4] Markel, M., 2012, *Technical Communication*, Palgrave Macmillan.
[5] Tuhovsky, I., 2019, *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills,* Rupa Publications India.
[6] Williams, R., 2014, *The Non-designer's Design Boo*k, Peachpit Press.