AMRITA VISHWA VIDYAPEETHAM
DEEMED TO BE UNIVERSITY
School of Engineering
Coimbatore Campus, Amritanagar P.O., Ettimadai,
Coimbatore - 641 112 Tamil Nadu, India Ph: +91 422 2685000
Fax: +91 422 2686274 Email: ase@amrita.edu

M.Tech Engineering Design

Curriculum and Syllabus

(2021 Admission Onwards)

M.TECH – ENGINEERING DESIGN

Department of Mechanical Engineering

This program is designed to enable an engineering graduate to develop specific capabilities in design, synthesis and analysis of a wide variety of mechanical engineering systems. The program focuses on developing design methodologies which involve high degree of research orientation supplemented with practical insights. Besides core courses (which are mandatory), a variety of electives are also offered to suit the taste of each individual student so that he/she can specialize in a particular area of Engineering Design. The students are periodically assessed by the teachers who are experts in chosen areas of Engineering Design, to ensure quality of education. On the whole, the Masters Program is committed to produce design engineers with excellent creative capabilities and calibre to solve real life problems curtailing to industry requirements, in tune with the objectives envisioned by the University

M Tech Engineering Design

1.0 Mission of the Department

M1	To develop in each student, a profound understanding of fundamentals, motivation for continuous learning, and practical problem-solving skills for building a successful career.
M2	To create and share technical knowledge and collaborate with Industry and Institutions for the betterment of Society.
M3	To imbibe ethical values, leadership skills and entrepreneurial skills in students.
M4	To sustain a conducive environment to involve students and faculty in research and development.

2.0 Program Educational Outcomes (PEOs)

PEO1	Develop and execute innovative methods and models to generate new ideas to realize successful products using modern tools and techniques.
PEO2	Conduct research by following ethical practices and intellectual integrity to provide cost-effective and sustainable solutions for industrial and societal problems.
PEO3	Collaborate and function effectively as an individual and team member in a professional career / entrepreneurship.

3.0 Program Outcomes (POs)

PO1	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO2	An ability to write and present a substantial technical report/document.
PO3	An ability to independently carry out research/investigation and development work to solve practical problems
PO4	An ability to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.
PO5	An ability to design, analyse and synthesize multi-physical engineering systems using modern tools and techniques.

Curriculum

First Semester

Course Code	Type	Course	L T P	Cr
21ED601	FC	Applied Mathematics	3 0 3	4
21ED602	FC	Optimization Techniques in Engineering	3 0 3	4
21ED651	SC	Advanced Solid Mechanics	3 0 0	3
21ED652	SC	Failure Analysis and Design	3 0 0	3
21ED653	SC	Theory of Vibrations	3 0 0	3
21ED681	SC	Engineering Design Lab	0 0 3	1
21HU601	HU	Amrita Values Programme*		P/F
21HU602	HU	Career Competency I*		P/F
			Credits	18

* Non-credit course

Second Semester

Course Code	Type	Course	L T P	Cr
21ED654	SC	Finite Element Techniques	3 0 3	4
21ED655	SC	Advanced Kinematics	3 0 0	3
21ED656	SC	Systems Engineering	2 0 0	2
21ED657	SC	Machine Learning for Engineering Design	3 0 3	4
	E	Elective I	3 0 0	3
21RM616	SC	Research Methodology & IPR	2 0 0	2
21HU603	HU	Career Competency II	0 0 3	1
			Credits	19

Third Semester

Course Code	Type	Course	L T P	Cr
	E	Elective II	3 0 0	3
	E	Elective III**	3 0 0	3
21ED798		Dissertation Phase I		10
			Credits	16

*Can opt for NPTEL/Swayam courses with the prior approval from the Department

Fourth Semester

Course Code	Type	Course	L T P	Cr
21ED799		Dissertation Phase II		16
			Credits	16

Total credits: 69

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
21ED601	Applied Mathematics	3 0 3	4
21ED602	Optimization Techniques in Engineering	3 0 3	4

Subject Core

Course Code	Course	L T P	Cr
21ED651	Advanced Mechanics of Solids	3 0 0	3
21ED652	Failure Analysis and Design	3 0 0	3
21ED653	Theory of Vibrations	3 0 0	3
21ED654	Finite Element Techniques	3 0 3	4
21ED655	Advanced Kinematics	3 0 0	3
21ED656	Systems Engineering	2 0 0	2
21ED657	Machine Learning for Engineering Design	3 0 3	4
21ED681	Engineering Design Lab	0 0 3	1

Electives

Course Code	Course	L T P	Cr
21ED701	Modelling, Simulation and Analysis of Engineering Systems	3 0 0	3
21ED702	Fundamentals of Analytical Dynamics	3 0 0	3
21ED703	Nonlinear Vibrations	3 0 0	3
21ED704	Multi-body Dynamics	3 0 0	3
21ED705	Advanced Robotics	3 0 0	3
21ED706	Introduction to Nonlinear Dynamics and Chaos	3 0 0	**3**
21ED707	Machining Dynamics	3 0 0	3
21ED708	Computational Fluid Dynamics	2 0 3	3
21ED709	Theory of Plates and Shells	3 0 0	3
21ED710	Mechanics of Composite Materials	3 0 0	3

21ED711	Fracture Mechanics	3	0	0	3
21ED712	Tribology	3	0	0	3
21ED713	Design for Manufacturing and Assembly	3	0	0	3
21ED714	Selection of Materials for Product Design	2	0	3	3
21ED715	Design Thinking	2	0	3	3
21ED716	Engineering Design-Product Architect	2	0	3	3
21ED717	Design for Additive Manufacturing	3	0	0	3
21ED718	Multi Objective Design Optimization	2	0	3	3
21ED719	Robust Design	3	0	0	3
21ED720	Machine Condition Monitoring	3	0	0	3
21ED721	Reliability Engineering	3	0	0	3
21ED722	Mechatronics System Design	3	0	0	3

21ED601 **APPLIED MATHEMATICS** **3-0-3-4**

Course Objectives:

1. Gain an understanding of errors in numerical methods and their propagation
2. Understand different numerical methods for the solution of algebraic equations
3. Analyse nonlinear ODEs using qualitative approach and to solve them using numerical methods
4. Recognize the three basic types of PDEs and to apply both analytic and numerical methods to the solution of important PDEs
5. To appreciate the power of abstraction through introduction and application of concepts like vector spaces, inner product spaces and linear transformations.

Course Outcomes:

CO	CO Description
CO01	Identify different errors and to quantify their propagation
CO02	Numerically solve single and system of nonlinear algebraic equations
CO03	Carry out qualitative analysis of nonlinear ODEs and to solve them numerically
CO04	Identify different types of PDEs and to solve them numerically
CO05	Find orthonormal basis for inner product spaces and to perform spectral decomposition of operators.

CO-PO Mapping:

CO	PO1	PO2	PO3	PO4	PO5
CO01	2	3	1	2	2
CO02	2	3	1	2	2
CO03	2	3	1	2	2
CO04	2	3	1	2	2
CO05	2	3	1	2	2

Skills acquired:

Use algebraic skills essential for the study of systems of linear/nonlinear algebra, PDE, vector spaces, perform error analysis and use computation tools to enhance understanding.

Course Syllabus:

Error Analysis: Accuracy and precision – Round-Off and Truncation errors, Taylors Series, Error propagation, Basic Applications: Interpolation and regression methods. Introduction to MATLAB and writing simple programs.

Algebraic Equations: Bisection method, Fixed point iteration, Newton Raphson method, Secant method, Methods to solve systems of nonlinear equations, Basic applications.

Differential Equations: Ordinary differential equations, qualitative analysis, state space and linearization, fixed points and their stability, basic examples. Euler's method, Runge Kutta methods, Systems of equations, Basic examples including nonlinear simple pendulum, vehicle models etc. Partial Differential Equations: Basic definitions. Model Equations: Elliptic, Parabolic and Hyperbolic PDEs. Solving PDEs Numerically - Elliptic, Parabolic and Hyperbolic Equations. Explicit methods, simple implicit methods, Crank-Nicholson method, Introduction to FEM.

Linear Algebra: Review of Matrix Algebra, systems of linear equations, matrices and matrix operations, Inverses, Determinants, Row reduction, Cramer's rule.– Vector Spaces – Sub Spaces – Linear Independence – Basis – Dimension – Change of basis – Null Space – Rank and Nullity – Inner Product – Orthogonality – Orthogonal Basis – Gram-Schmitt Process. Linear and inverse linear transformations – Spectral theorem for Hermitian operators

.**Text Books/ References:**

1. C.F Gerald and P.O Wheatley, "Applied Numerical Analysis", Seventh Edition, Addison Wesley, 2009.
2. M.K.Jain, S.R.K. Iyengar and R.K.Jain, "Numerical Methods for Scientific and Engineering Computation", New Age International Publishers, Fifth Edition, 2007.
3. Howard Anton, and Chris Rorres "Elementary Linear Algebra: Applications", Tenth Edition, Tata Wiley, 2010.
4. Gilbert Strang, "Linear Algebra and Its Applications", Fourth Edition, Cengage, 2006.
5. K. Hoffman and R. Kunze, "Linear Algebra", PHI, 2002.
6. E Kreyszig, "Advanced Engineering Mathematics" E Kreyszig, John Wiley and Sons, Tenth Edition, 2015.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	15	-
Continuous Assessment (Lab)*	30	-
End Semester	-	35

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED602 OPTIMIZATION TECHNIQUES IN ENGINEERING 3-0-3-4

Course Objectives:

1. Introduce the traditional and modern methods of optimization techniques used for solving non-linear unconstraint and constraint engineering optimization problems.
2. Considering the computational aspects, the course will involve a significant number of computational assignments using software tools and a term project in the area of engineering optimization.

Course Outcomes:

CO	CO Description
CO01	Formulate the engineering problems as an optimization problem
CO02	Apply necessary and sufficient conditions for a given optimization problem for optimality
CO03	Select appropriate solution methods and strategies and solve optimization problems
CO04	Justify and apply the use of modern heuristic methods for solving complex optimization problems to obtain optimal / near-optimal solution
CO05	Interpret and analyse the solution obtained by optimization algorithms and improve their convergence and solution quality
CO06	Solve Engineering Design and Manufacturing related optimization problems using software tools.

CO-PO Mapping:

CO	PO1	PO2	PO3	PO4	PO5
CO01	3	2	2	2	2
CO02	3	2	2	2	2
CO03	3	2	2	2	2
CO04	3	2	2	2	2
CO05	3	2	2	2	2
CO06	3	2	2	2	2

Skills Acquired:

Formulate the engineering problems as an optimization problem; Select appropriate solution methods and strategies and solve optimization problems; Solving complex optimization problems using heuristic/ meta heuristic approach; Solve Engineering Design and Manufacturing related optimization problems using software tools.

Course Syllabus:

Introduction to Optimization - Engineering applications - Statement of an optimization problem - Classification - Optimal problem formulation: Problems in design and manufacturing fields - Optimality criteria - Classical optimization techniques - Kuhn-Tucker (KT) optimality conditions.

Non-linear programming algorithms: One-dimensional problem, Unconstrained optimization problem, Constrained optimization problem - Transformation methods - Interior and exterior penalty function method - Convergence and divergence of optimization algorithms - Complexity of algorithms.

Modern Methods in Optimization: Genetic Algorithm - Simulated Annealing - Particle Swarm Optimization - Neural Network-based optimization - Optimization of Fuzzy systems - Multi-Objective optimization – Optimization in the probabilistic domain - Shape and Topology optimization - Data Analytics and optimization using Machine learning approach.

Lab Practice:

Implementing optimization algorithm using software tools / Programming for solving Engineering Design / Manufacturing related problems

- Checking the optimality of unconstraint and constraint optimization problems using the Hessian matrix.
- Solving Linear, Mixed Integer, Quadratic, Non-Linear Unconstrained, and Constrained optimization problems using direct and gradient-based algorithms.
- Implementing Modern methods of optimization namely GA, SA, and PSO for solving large scale linear and complex non-linear optimization problems
- Statistical modeling and Parameter optimization
- Multi-objective optimization using Evolutionary Multi-Objective Optimization algorithms
- Case studies / Project / Presentation / Report writing: Optimal design of real-world engineering problems

Text / Reference Books:

1. Rao, Singiresu S, “Engineering optimization: theory and practice”. John Wiley & Sons, 2019.
2. Deb, Kalyanmoy, “Optimization for engineering design: Algorithms and examples”. PHI Learning Pvt. Ltd., 2012.
3. Arora, J.S, “Introduction to Optimum Design”, Academic Press, 4th Edition, 2017.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	15	-
Continuous Assessment (Lab)*	30	-
End Semester	-	35

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED651 ADVANCED SOLID MECHANICS 3-0-0-3

Course Objectives:

1. Establish the concepts of continuum theory and apply the principles of indicial notations, tensors, and transformations to demonstrate the characteristics of motion and deformation.
2. Inculcate the knowledge to formulate & solve continuum-based problems in the area of Solid Mechanics.
3. Inculcate the concepts of deformation, strain, and stress measures for the case of finite and infinitesimal deformations for different load bearing members under different configurations.
4. Familiarize methods to solve and analyze special problems like torsion in prismatic bars, and stresses & deflections in beams subjected to unsymmetrical bending.

Course Outcomes:

CO1	Demonstrate and solve the characteristics of motion and deformation of continua utilizing the concepts of indicial notations, tensors, and transformations, based on the continuum theory
CO2	Develop and apply material constitutive laws, compatibility conditions, and governing equations using different measures of stresses and strains
CO3	Formulate and solve continuum-based problems in the area of Solid Mechanics for different loading conditions
CO4	Analyze stresses, strains, and deflections using the Energy method
CO5	Analyze special problems like torsion in prismatic bars, and stresses & deflections in beams subjected to unsymmetrical bending

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2	2	0
CO2	3	3	0	2	0
CO3	3	3	0	2	0
CO4	3	3	0	2	1
CO5	3	3	0	2	3

Skills Acquired:

Develop analytical models based on continuum theory to formulate and solve linear elastic problems in the area of Solid Mechanics, using material constitutive laws, compatibility conditions, and governing equations, and also to analyze stresses, strains, and deflections in continua under varying loading conditions.

Course Syllabus:

Introduction to Continuum Theory & Continuum Approach: Vectors and Tensors, Stress Tensor & Principles, Kinematics of Deformation and Motion, Analysis of stress and strain, Planar problems: Plane Stress and Plane Strain, Axisymmetry, Mohr's circle for three dimensional stresses. Fundamental Laws and Equations, Continuum Models in Solid Mechanics: Linear Elasticity: Elasto-Statics, Elasticity problems in multi-dimensions.

Energy method for analysis of stress, strain and deflection: Theorem of virtual work, Theorem of least work, Castiglioni's theorem, Rayleigh Ritz method, Galerkin's method, Elastic behavior of anisotropic materials like fiber reinforced composites.

Beam theory & Shell theory, Failure Criteria, Introduction to Plasticity.

Special Problems/Case Studies:

Torsion of prismatic bars for solid section and thin walled section: Analogies for torsion: Membrane analogy. Thin walled members of open cross section in which some sections are prevented from warping, Torsion of non-circular shafts.

Concept of shear center in symmetrical and unsymmetrical bending, stress and deflections in beams subjected to unsymmetrical bending, shear center for thin wall beam cross section, open section with one axis of symmetry, general open section, and closed section.

Text Books/References:

1. Sadd, Martin H., "Elasticity: Theory, applications and Numeric", Academic Press, 2005.
2. Michael Lai W., David Rubin, and Erhard Krempl, "Introduction to Tensor Calculus and Continuum Mechanics", Fourth Edition, Butterworth Heinemann, 2010.
3. L. S. Srinath, "Advanced Mechanics of Solids", Third Edition, Tata McGraw-Hill, 2009.
4. S. P. Timoshenko and J. N. Goodier, "Theory of Elasticity", Third Edition, Tata McGraw-Hill, 2010.
5. Boresi, A.P. and K. P. Chong, "Elasticity in Engineering Mechanics", Second Edition, John Wiley & Sons, 2000.
6. Gerhard A. Holzapfel, "Non-linear Solid Mechanics- A Continuum Approach for Engineering", Wiley, 2000.
7. Morton E. Gurtin, Eliot Fried, and Lallit Anand, "The Mechanics and Thermodynamics of Continua", Cambridge, 2009.
8. Roger Temam and Alian Miranville, "Mathematical Modeling in Continuum Mechanics", Cambridge University Press, 2005.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED652 FAILURE ANALYSIS AND DESIGN 3 0 0 3

Course objectives:

1. Familiarize with various failure modes of mechanical components.
2. Impart the knowledge in defect identification and component life prediction.

Course outcomes:

CO	CO Description
CO1	Recognize and describe common engineering failure mechanisms
CO2	Identification of defects in a machine components
CO3	Predict the life of the components using fatigue, fracture and creep
CO4	Analyse the failed engineering components

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO1	3	2	0	2	0
CO2	3	2	1	2	2
CO3	3	2	0	2	0
CO4	3	2	1	2	2

Skills Acquired:

Perform analysis of failure components with the knowledge of various failure modes. Students also acquire the skills to identify the defects in machinery components using non-destructive testing methods and machine condition monitoring techniques.

Course Syllabus:

Introduction, causes of failures, classification, steps in failure analysis, tools, sample selection and treatment, materials analysis, equipments, Metallography, commonly used Non-destructive testing methods. Machine condition monitoring techniques.

Failure mechanisms, Failure theories, elastic deformation, plastic deformation, ductile and brittle fracture, ductile to brittle transition, Fracture mechanics approach in design.

Fatigue Fracture, Macroscopic and Microscopic Characteristics, Statistical aspects of fatigue, Fatigue failure prediction and life assessment.

Wear failures, adhesive, abrasive, erosive and corrosive wear.

Elevated temperature failures, creep, creep crack branching, thermal fatigue, microstructural instability and oxidation.

Corrosion failures, types and their identification.

Failure analysis techniques, failures in rotating machine components shaft, bearing and gear.

Text Books/References:

1. Jones D. R. H., “Engineering Materials 3 – Materials Failure Analysis: Case Studies and Design Implications”, Pergamon Press, 1993.
2. ASM Handbook, Vol. 11, “Failure Analysis and Prevention” Edited by, ASM Publications, 2002.
3. Arthur J.McEvily, Jirapong Kasivitamnuay., “ Metal Failures: Mechanisms, Analysis and Prevention”, Wiley, 2013
4. Ralph I. Stephens, Ali Fatemi, Robert R. Stephens, Henry O.Fuchs , “Metal fatigue in Engineering”, Wiley, 2001.
5. Colangelo Vito J. and Heiser F., “Analysis of Metallurgical Failures”, Second Edition, John Wiley & Sons, Inc., 1987.
6. Briant C. L., “Metallurgical Aspects of Environmental Failures”, Elsevier Science Publishers, 1985.
7. Robert Bond Randall, “Vibration-Based Condition Monitoring: Industrial, Aerospace and Automotive Applications”, John Wiley & Sons, 2011.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED653 THEORY OF VIBRATIONS 3-0-0-3

Course Objectives:

1. Mathematically model and analyze vibration systems
2. Understand the importance of vibration analysis in design of dynamical systems

Course Outcomes:

CO	CO Description
CO01	Perform free and forced vibration analysis of single degree of freedom systems.
CO02	Perform free and forced vibration analysis of two and multi degree of freedom systems.
CO03	Apply the properties of vibration systems to perform modal analysis.
CO04	Analyze free vibration characteristics of continuous systems.
CO05	Apply approximate methods to study the vibration characteristics of discrete and continuous systems.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	2	2
CO02	3	2	1	2	2
CO03	3	2	1	2	2
CO04	3	2	1	2	2
CO05	3	2	1	2	2

Skills Acquired

Develop mathematical models for the vibration systems and use analytical and numerical tools to understand the underlying dynamics to help the design of systems. Students also acquire the skills to correlate the experiments findings with the mathematical models.

Course Syllabus

Vibration of single degree of freedom systems – free and forced vibrations – rotating unbalance, support excitation, whirling of shafts, vibration isolation, vibration measurement. Response to arbitrary excitation – convolution integral, method of Fourier transforms. Types of damping – equivalent viscous damping.

Vibration of two degree of freedom systems – formulation and solution of matrix eigenvalue problem. Elastic and inertial coupling, Orthogonality of modes. Response of two dof system to harmonic excitation – undamped and damped vibration absorbers.

Vibration of multi dof system – Lagrange's equation. Formulation and solution of matrix eigenvalue problem. Orthogonality of modal vectors – expansion theorem – modal analysis. Forced vibration - general formulation. Rayleigh's quotient and its properties.

Vibration of continuous systems – transverse vibration of a string, axial vibration of rod, torsional vibration of shaft, bending vibration of beam – differential eigenvalue problem, natural frequencies and modes – Orthogonality of eigen functions. Rayleigh Ritz, Assumed modes and Galerkin method.

Text Books/ References:

1. L. Meirovitch, "Fundamentals of vibrations", McGraw Hill higher education, 2001.
2. W.T Thomson, M.D Dahleh and C.Padmanabhan, "Theory of vibration with applications", 5th edition, Pearson education, 2014.
3. S.S Rao, "Mechanical vibrations", 5th edition, Prentice Hall, 2011
4. B.H Tongue, "Principles of vibration", Oxford University press 1996.
5. J.P Den Hartog, "Mechanical vibrations", Dover publications, 1985.
6. D.J Inman, "Engineering Vibration", Pearson, 2014.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED654 FINITE ELEMENT TECHNIQUES 3-0-3-4

Course Objectives:

1. Inculcate the knowledge to develop finite element programs to solve 1D and Multi-D problems using different FE procedures.
2. Inculcate the knowledge to formulate Strong, Weak, Galerkins, and Matrix forms to formulate and solve linear and non-linear multi-physics problems using the method of weighted residuals.
3. Utilize commercial finite element packages to model, solve, and analyze real-world industrial problems.

Course Outcomes:

CO1	Classify and develop different finite element procedures to solve simple 1D and 2D static problems like bars, beams, trusses, frames, etc.
CO2	Formulate basic and higher order elements with applicability to 1D and Multi-D coordinate systems
CO3	Formulate and solve static and dynamic/transient problems in Solid Mechanics and Heat Transfer using the Method of Weighted Residuals
CO4	Estimate finite element assembly procedure by constructing ID, IEN, LM arrays
CO5	Develop finite element models to solve and analyze, static and dynamic, linear and non-linear multi-physics problems using a finite element package

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	0	0	0
CO2	3	3	0	0	0
CO3	3	3	0	2	1
CO4	3	3	0	0	0
CO5	3	3	1	2	3

Skills Acquired:

Develop analytical and numerical models using the methodology of finite elements to solve and analyze linear and nonlinear problems involving single and multi-physics, and to effectively utilize commercial finite element packages for part and process modeling with applicability to real-world industrial problems.

Course Syllabus:

Fundamentals of governing equations in Solid Mechanics and Heat Transfer. Basic finite element procedures: Direct Stiffness Method, Principle of Minimum Potential Energy, Strong form, Weak form or Variational formulation, Weighted Residual Method - Galerkin formulation, Formulation of the finite element equations - Element types - Basic and higher order elements –1D, 2D, 3D coordinate systems. Finite elements in Solid Mechanics: Analysis of trusses, beams and frames, Plane stress, Plane strain and Axisymmetric elements, Isoparametric formulation and elements.

Finite elements in Heat Transfer: Formulation and solution procedures in 1D and 2D problems – Steady State and Transient problems.

Structural Dynamics: Formulation - Element mass matrices - Evaluation of Eigen values and Eigen vectors - Natural frequencies and mode shapes - Numerical time integration. Computer implementation of the Finite element method: Pre-processing, Element calculation, Equation assembly – Assembly Flowchart, ID, IEN, LM arrays, Solving – Numerical Integration – Gaussian Quadrature, Post processing – Primary and Secondary variables.

Lab Practice:

Static linear and non-linear analysis of thermo-mechanical and other coupled-physics problems, Problems involving discontinuous interactions, Modal analysis to capture natural frequencies and mode shapes, Steady-state dynamic analysis of problems involving harmonic loading and predict conditions for resonance, Transient dynamic analysis of mechanical and industrial processes like machining, rolling, extrusion-forming, punching, etc., Problems related to Topology Optimization, Utilize non-default controls available in FE packages for specific applications, Develop & Run script files for simple problems without using GUI, Develop user-defined codes and plug-ins for specific applications. (Tool: Abaqus)

TEXT BOOKS/REFERENCES:

1. Thomas J. R. Hughes, “The Finite Element Method – Linear Static and Dynamic Finite Element Analysis”, Dover Publications Inc, 2003.
2. Rao S. S., “The Finite Element Method in Engineering”, Fourth Edition, Elsevier, 2007.
3. Daryl L. Logan, “A First Course in the Finite Element Method”, Fourth Edition, Cengage Learning, 2007.
4. David V. Hutton, “Fundamentals of Finite Element Analysis”, McGraw Hill, 2005.
5. Reddy J. N., “An Introduction to the Mathematical Theory of Finite Elements”, Dover Publications, 2011.
6. Zienkiewicz O. C., “The Finite Element Method for Solid and Structural Mechanics”, Sixth Edition, Butterworth-Heinemann, 2005.
7. Jacob Fish and Ted Belytschko, “A First Course in Finite Elements”, Wiley Inter Science, 2007.
8. DS Simulia, “Abaqus Documentation”, Abaqus version 6.16.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	15	-
Continuous Assessment (Lab)*	30	-
End Semester	-	35

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED655 ADVANCED KINEMATICS 3-0-0-3

Course Objectives:

1. Synthesize and analyze complex planar and spatial mechanisms
2. Design of complex mechanisms for various applications

Course Outcomes:

CO	CO Description
CO01	Perform kinematic synthesis and analysis of planar mechanisms.
CO02	Multibody formulation analysis of planar and spatial mechanisms.
CO03	Perform manipulator kinematic formulation and analysis.
CO04	Synthesize and analyses mechanisms for different applications.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	2	2
CO02	3	2	1	2	2
CO03	3	2	1	2	2
CO04	3	2	1	2	2

Skills Acquired:

Perform kinematic synthesis and analysis of planar and spatial mechanisms and apply the concepts to develop complex mechanisms for various applications.

Course Syllabus:

Review of kinematics of planar mechanisms. Kinematic analysis of planar mechanisms (graphical and analytical approaches)

Kinematic synthesis of mechanisms for motion, function and path generation. Analytical synthesis of mechanisms.

Multibody formulation for analysis of planar and spatial mechanisms

Introduction to Manipulator Kinematics Transformations, Different Notations, Forward, and Inverse Kinematics.

Differential Kinematics and Statics: Jacobian matrix and Workspace Singularities. Manipulator Dynamics: Forward and Inverse Dynamics. Lagrangian and Newton-Euler Formulations.

Textbook / Reference Books

1. Mallik, Ashok Kumar, Amitabha Ghosh, and Gunter Dittrich, “Kinematic analysis and synthesis of mechanisms”, CRC Press, 1994.
2. Hartenberg, Richard, and Jacques Danavit, “Kinematic synthesis of linkages”, New York: McGraw-Hill, 1964.
3. Shabana, Ahmed A, “Computational dynamics”, John Wiley & Sons, 2009.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc,

21ED656 **SYSTEMS ENGINEERING** **2-0-0-2**

Course Objectives:

1. To understand the basic tenets of complex systems analysis
2. Analyse different properties of complex systems like hierarchy, auto-organisation and emergence
3. Apply different holistic approaches like dynamical systems, system dynamics, and agent based modelling to the study of complex systems.

Course Outcomes:

CO	CO Description
CO01	Apply different holistic approaches to the study of complex systems
CO02	Understand properties of complex systems like hierarchy, auto-organization and emergence.
CO03	Model and analyze complex systems using dynamical systems approach.
CO04	Analyze complex systems using causal loop diagrams and stock and flow diagrams.
CO05	Apply agent based modelling to analyze complex systems.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	2	2
CO02	3	2	1	2	2
CO03	3	2	1	2	2
CO04	3	2	1	2	2
CO05	3	2	1	2	2

Skills Acquired:

Model and analyze large order systems using concepts in systems engineering; Develop causal loop diagrams using software; Analysis of industrial problems with tools learned in the course.

Course Syllabus:

Systems science and systems engineering – motivation and examples. Definition of systems, examples. Reductionist approach and limitations. Holism and systems science. Basic tenets of systems engineering, general principles, classification of systems, systems in the world and systems in the mind. Systems definition of complexity, examples, structural and functional hierarchies, formation of complex systems, auto-organisation, emergent phenomena, systems and networks, multiple spatial and time scales, evolution of systems, adaptive systems, systems of systems. Nonlinearity and chaos in complex systems. System Dynamics – system modelling, types of models. Causal loop diagrams, feedback loops, examples. Stock and flow diagrams, governing difference equations, stock and flow with delay, examples. Simulation of systems in

STELLA. Agent based modelling – agents and modelling, creating simple agent based models using NETLOGO, components of agent based models – agents, environments and interactions. Examples of agent based models.

Textbook / Reference Books:

1. G. E. Mobus and M. C. Kalton, Principles of systems science, Springer Science, Newyork, 2015.
2. INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. 4^{th} Edition, John Wiley, 2015.
3. Alexander Kosiakoff, William N. Sweet, Samual J. Seymour, Steven M.Biemer, Systems Engineering Principles and practice, 2^{nd} Edition, John Wiley, 2011.
4. B. K. Bala, F. M. Arshad, K. M. Noh, System Dynamics – Modelling and Simulation, Springer Science, Newyork, 2017.
5. U. Willensky, W. Rand, An introduction to agent based modelling, MIT Press, 2015.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc,

21ED657 MACHINE LEARNING FOR ENGINEERING DESIGN 3-0-3-4

Course Objectives:

1. Understand various machine learning methods and its applications
2. Impart the knowledge to formulate a machine learning model for design of mechanical systems.
3. Enable python programming skills for scientific computing

Course Outcomes:

CO	CO Description
CO01	Apply linear algebra and probability theory to practical problems
CO02	Apply regressions methods to practical machine learning situations
CO03	Understand the architecture and parameters involved in neural networks
CO04	Use different types of clustering methods
CO05	Apply machine learning techniques to solve problems pertinent to mechanical design

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	3	1	2	3
CO02	3	3	1	2	3
CO03	3	3	1	2	3
CO04	3	3	1	2	3
CO05	3	3	1	2	3

Skills Acquired:

Formulate the engineering problems as a machine learning problem; Select appropriate solution methods and strategies to solve machine learning problems; Solve engineering design related machine learning problems using software tools.

Course Syllabus:

Basic motivation, examples of machine learning applications, supervised and unsupervised learning – Review linear algebra, vector spaces, linear transformations, Eigen values and vectors – Review of statistics and probability theory, random variables, probability distributions – Linear Regression in one variable, Gradient descent, Regression in multiple variables – Linear models for classification, Discriminant functions, Logistic regression – Regularization, over and under fitting, Regularized linear regression, Regularized logistic regression – Classification, Decision Tree, Support Vector Machine, Naïve Bayes – Neural networks model representation, Feed-forward network functions, Network training, Back-propagation algorithm – Clustering, Mixture densities, K-Means clustering, Expectation maximization, Spectral clustering –Dimensionality reduction, Principal component analysis, Singular value decomposition – Reinforced learning – Fundamentals of deep learning – Application of machine learning in mechanical design, case studies in dynamics, fault analysis, system control, modelling etc.

Lab Practice:

Python packages for scientific computing: Numpy, SciPy, Pandas, Scikit-learn. Data analysis with python; Concepts of data preparation; Time series data analysis. Introduction to machine learning; Extraction of features for machine learning methods; Linear regression, logistic regression, decision tree. Data visualization.

Machine learning methods for predictive maintenance, condition monitoring, autonomous vehicles: Multivariate time series prediction; Support vector machines; Recurrent neural networks: convolution neural networks. An introduction on few python machine learning packages: Tensor flow; Keras and PyTorch.

Textbook / Reference Books:

1. Tom M. Mitchell, "Machine Learning", McGraw Hill, 1997.
2. Ethem Alpaydin, "Introduction to Machine Learning", MIT Press, 2014.
3. C. M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2006.
4. A. C. Muller and S. Guido, "Introduction to Machine Learning with Python", O'Reilly Media, 2016.
5. A. C. Faul, "A Concise Introduction to Machine Learning", CRC Press, 2020.
6. Guttag, John., "Introduction to Computation and Programming Using Python: With Application to Understanding Data", Second Edition. MIT Press, 2016.
7. William McKinney, "Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython", Second edition, Shroff/O'Reilly, 2017.
8. Hans Fangohr, "Introduction to Python for Computational Science and Engineering (A beginner's guide)",Faculty of Engineering and the Environment University of Southampton, 2015.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	15	-
Continuous Assessment (Lab)*	30	-
End Semester	-	35

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21RM616 RESEARCH METHODOLOGY & IPR 2-0-0-2

Course Objectives

1. To develop an understanding of the basic framework of research process
2. To identify various sources of information for literature review and data collection
3. To develop an understanding of the ethical dimensions of conducting applied research

Course Outcomes:

CO	CO Description
CO01	Understand research problem formulation
CO02	Analyse research related information
CO03	Follow research ethics
CO04	Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
CO05	Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular
CO06	Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits

CO-PO Mapping:

	PO1	PO2	PO3	P04	PO5
CO01	1	1	2	-	-
CO02	1	1	3	-	-
CO03	1	1	2	-	-
CO04	1	0	3	-	-
CO05	1	1	2	-	-
CO06	1	1	2	-	-

Skills Acquired:

Research problem identification, solution strategies, research ethics, report writing, IPR

Course Syllabus:

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Effective literature studies approaches, analysis Plagiarism, Research ethics.

Effective technical writing, how to write report, Paper, Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Text Books/References:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students", Juta & Co. Ltd., 1996.
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction", Juta & Co. Ltd., 2004.
3. Ranjit Kumar, 3rd Edition, "Research Methodology: A Step-by-Step Guide for beginners",SAGE Publications, 2010.
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.
6. Niebel, "Product Design", McGraw Hill, 1974.
7. Asimov, "Introduction to Design", Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
9. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Evaluation Pattern:

Evaluation Components	Internal	External
Continuous Assessment	70	-
End Semester	-	30

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

21ED681 ENGINEERING DESIGN LAB 0-0-3-1

Course Objectives:

1.Understand the mechanical behavior of materials under various types of loading.

2.Inculcate the knowledge on signature analysis for Machinery fault detection.

3. Familiarise advanced vibration testing for design of dynamic systems

Course Outcomes:

CO	CO Description
CO01	Conduct various testing on materials to understand its mechanical behavior and determine its properties.
CO02	Analyse the sound and vibration signals for fault diagnosis
CO03	Perform various vibration testing and analysis for design of mechanical systems

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	2	3	2
CO02	3	2	2	3	2
CO03	3	2	2	3	2

Skills Acquired:

Determine the mechanical properties of the material by conducting various material testing; Detection of machinery faults using signature analysis; Design dynamic mechanical systems by performing vibration testing.

Course Syllabus:

Material Testing and Measurement:

Tensile Testing of Composite Materials, Photo elastic stress measurement, Charpy Impact Test, Fatigue and Creep Testing. Wear Testing with a Pin-on-Disc Apparatus, Corrosion Testing of Steel and Aluminium. Measurement of surface roughness, Measuring strain with strain gauges, Residual stress measurement using hole drilling apparatus.

Machine Condition Monitoring:

Machinery Vibration and Sound data Acquisition, Signal Conditioning, Signature Analysis and Machine Condition Monitoring using virtual instrumentation tools. IoT based Condition Monitoring.

Advanced Vibrations Testing Lab:

Free vibration analysis – determination of natural frequency, logarithmic decrement, damping factor using time domain method. Forced vibration – frequency response plots – half power point method. Experimental Modal analysis. Determination of natural frequency and modes using software package.

Evaluation Pattern:

Evaluation Components	Internal	External
Continuous Assessment (Lab)*	80	-
End Semester	-	20

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

21ED701 MODELING, SIMULATION AND ANALYSIS OF ENGINEERING SYSTEMS 3-0-0-3

Course Objectives:

1. Mathematically model and analyze physical systems using time and frequency domain methods.
2. Perform stability analysis and optimal control of engineering systems.

Course Outcomes:

CO	CO Description
CO01	Perform mathematical modeling of physical systems using fundamental principles.
CO02	Analyze the mathematical models using time and frequency domain methods
CO03	Perform state space analysis of linear time invariant systems
CO04	Perform optimal control design for engineering systems

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	2	2
CO02	3	2	1	2	2
CO03	3	2	1	2	2
CO04	3	2	1	2	2
CO05	3	2	1	2	2

Skills Acquired:

Formulate mathematical models for physical systems based on fundamental laws governing their behavior and understand their behavior using analytical methods. Perform stability analysis and design proper control systems.

Course Syllabus:

Introduction to linear systems, principle of super position-Modelling of engineering systems-mechanical, electrical, fluid, thermal and mixed discipline systems-Free, forced and transient response of first and second order systems-Solution of differential equation using Laplace Transforms-Time domain and Frequency domain analysis-State space representation-System characteristics from state space representation-Solving the state equations-Stability criterion through the state transition matrix-Control system design in state space-Linear optimal control. System identification. Introduction to Nonlinear systems

Text Books/References:

1. Philip D. Cha, James J. Rosenberg, and Clive L. Dym, “Fundamentals of Modelling and Analysis of Engineering Systems”, Cambridge University Press, 2000.
2. Woods Robert L. and Lawrence Kent L., “Modelling and Simulation of Dynamic Systems”, Prentice Hall, 1997.
3. Ashish Tiwari, “Modern Control Design with MATLAB and SIMULINK”, John Wiley, 2002.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED702 FUNDAMENTALS OF ANALYTICAL DYNAMICS 3-0-0-3

Course Objectives:

1. Make students familiar with the different formalisms in analytical dynamics.
2. Enable the students to derive the equations of motion for multi-body dynamical systems and perform analysis using advanced concepts in dynamics.

Course Outcomes:

CO	CO Description
CO01	Analyse mechanical systems using Newtonian framework
CO02	Use virtual work and variational calculus to analyse systems
CO03	Arrive at governing equations using Lagrangian and Hamiltonian formalisms
CO04	Apply coordinate transformations to study practical problems
CO05	Use Legendre and canonical transformations to analyse systems

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	2	3	1	1	2
CO02	3	3	1	1	3
CO03	3	3	1	1	3
CO04	3	3	1	1	2
CO05	3	3	1	1	2

Skills Acquired:

With the knowledge gained from the course, the students will acquire skills to analyze dynamical systems in a broader perspective.

Course Syllabus:

Newtonian mechanics – Newton’s laws, impulse, momentum, moment of a force, angular momentum, work and energy. Systems of particles, two-body central force problem. Analytical mechanics – Generalised coordinates, constraints, fundamentals of variational calculus, principle of virtual work, D’Alembert’s principle, Hamilton’s principle, Lagrange’s equations of motion. Motion relative to rotating reference frames – Transformation of coordinates, rotating coordinate systems, motion relative to moving frames. Rigid body dynamics – Rigid body kinematics, linear and angular momentum, translation theorem for angular momentum, kinetic energy of a rigid body, principal axes, equations of motion, Euler’s angles.

Hamiltonian mechanics – The principle of least action, the Legendre transformation, Hamilton's equations, Poisson's brackets, canonical transformations, Hamilton-Jacobi equations.

Text Books/References:

1. Leonard Meirovitch, "Methods of Analytical Dynamics", Dover Publications, NewYork, 2012.
2. Goldstein H., Poole C. P., and Safko J. L., "Classical Mechanics", Third Edition, Pearson Education, 2014.
3. Woodhouse N. M. J., "Introduction to Analytical Dynamics", Springer Verlag, London, 2009.
4. Francis C. Moon, "Applied Dynamics", John Wiley & Sons, New York, 2008.
5. Haim Baruh, "Analytical Dynamics", McGraw Hill International, 1999.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED703 **NONLINEAR VIBRATIONS** **3-0-0-3**

Course Objectives:

1. Qualitatively and quantitatively investigate the dynamics of nonlinear systems.
2. Make use of the methodologies and tools in nonlinear dynamics for the solution of practical problems.
3. Incorporate nonlinearity in physical systems to improve its performance.

Course Outcomes:

CO	CO Description
CO01	Qualitatively investigate the behavior of nonlinear systems.
CO02	Apply perturbation techniques to solve nonlinear vibration problems.
CO03	Analyze free and forced vibration of single and multi-degree of freedom nonlinear systems.
CO04	Apply the methods and tools in nonlinear dynamics to practical problems.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	2	2	2
CO02	3	2	2	2	2
CO03	3	2	2	2	2
CO04	3	2	2	2	2
CO05	3	2	2	2	2

Skills Acquired:

Identify the influence of different types of nonlinearities in engineering systems and perform analysis to understand the underlying dynamics which help to improve the design of physical systems.

Course Syllabus:

Linear and nonlinear systems-conservative and non-conservative systems-potential well, phase planes, fixed points, periodic, quasi-periodic and chaotic responses; local and global stability- bifurcations. Equations of motion – linearization techniques, ordering techniques – Duffing, Van der Pol and Mathieu Hill equations. Analytical solutions – perturbation techniques - method of multiple scales, averaging method (KBM) – Harmonic balance method.

Bifurcations of periodic solutions. Numerical techniques – time response, phase plots, FFT, Poincare’ maps, strange attractors, Lyapunov exponents, basins of attraction, cell mapping techniques, Floquet theory.

Examples – free and forced vibration of Duffing oscillator – primary, sub harmonic, super harmonic resonances, jump phenomenon, multiple solutions, and combination resonances. Van der Pol oscillator – limit cycle oscillation - entrainment – synchronization. Parametrically excited systems – Mathieu's equation. Discontinuous nonlinear systems - Stick-slip oscillator, Impact oscillator.

Vibration of multi dof nonlinear systems – modal interactions, internal resonance

Applications in vibration isolation, absorption, energy harvesting and synchronization.

Text Books/References:

1. Nayfeh A. H. and Mook D. T., "Nonlinear Oscillations", Wiley-Interscience, 2008
2. Steven H. Strogatz, "Nonlinear Dynamics and Chaos", Reading, Addison-Wesley,2000.
3. Hayashi C., "Nonlinear Oscillations in Physical Systems", McGraw-Hill, 2014.
4. Thomsen J. J., "Vibrations and Stability, Advanced Theory, Analysis and Tools", Springer, 2003.
5. Nayfeh A. H. and Balachandran B., "Applied Nonlinear Dynamics", Wiley, 2008.
6. Seydel R., "From Equilibrium to Chaos: Practical Bifurcation and Stability Analysis", Elsevier, 1988.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED704 **MULTI BODY DYNAMICS** **3-0-0-3**

Course Objectives:

1. Formulate and solve for dynamics of connected bodies using multi-body dynamics formulations.
2. Develop algorithms and write computer programs to solve multi-body dynamic problems.

Course Outcomes:

CO	CO Description
CO01	Perform analytical formulation and solution of planar mechanisms.
CO02	Formulate and solve multi-body dynamic problems using different techniques.
CO03	Perform analysis of spatial mechanisms using multi-body dynamics formulation.
CO04	Write computer programs to solve multi-dynamics problems.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	2	2
CO02	3	2	1	2	2
CO03	3	2	1	2	2
CO04	3	2	1	2	2
CO05	3	2	1	2	2

Skills Acquired:

Formulation of kinematic and dynamic problems using multibody dynamics framework and solve them analytically or numerically to understand the behavior. This will help to make the design process simpler.

Course Syllabus:

Introduction - Motion and constraints – degrees of freedom – kinematic and dynamic analysis – dynamical equations in different forms – planar and spatial dynamics. Kinematics of rigid bodies – velocity and acceleration equations – constrained kinematics- formulation of driving and joint constraints – computational methods in kinematics. Forms of dynamic equations – D'Alembert's principle – Newton Euler equations – constrained dynamics – augmented formulation – embedding techniques – amalgamated formulation. Virtual work and Lagrangian dynamics – constrained dynamics – elimination of constrained forces – Lagrangian multipliers – state space representation – algorithm and sparse matrix implementation. Spatial dynamics – Euler angles – Dynamic equations of motion – constrained dynamics – Newton Euler equations– linear and angular momentum.

Textbooks /References:

1. Shabana A. A., “Computational Dynamics”, Third Edition, John Wiley, 2010.
2. Shabana A. A., “Dynamics of Multibody Systems”, Fourth Edition, Cambridge University Publications, 2013.
3. Nikravesh P. E., “Planar Multibody Dynamics-formulation, Programming and Applications”, CRC Press, 2007.
4. Nikravesh P. E., “Computer Aided Analysis of Mechanical Systems”, Prentice Hall, 1988.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED705 ADVANCED ROBOTICS 3-0-0-3

Course Objectives:

1. To Impart knowledge on the fundamentals of industrial robots
2. To give the exposure on kinematics, dynamics and trajectory planning for industrial robots

Course Outcomes:

CO	CO Description
CO01	Select the suitable robot for the application and estimate the appropriate gripping force
CO02	Analyse the forward and inverse kinematics for serial manipulator
CO03	Analyse the forward and inverse kinematics for parallel manipulator
CO04	Analyse the forward and inverse dynamics for serial manipulator
CO05	Develop the suitable trajectory algorithm for the given application

CO-PO Mapping:

COs	PO1	PO2	PO3	PO4	PO5
CO01	3	3	1	2	2
CO02	3	3	2	2	2
CO03	3	3	2	2	2
CO04	3	3	2	2	2
CO05	3	3	2	2	2

Skills acquired:

Select and design the gripper based on the gripper force analysis. To develop the inverse kinematics, forward dynamics solutions, and optimal trajectory without any singularities and enhance the operational feasibility.

Course Syllabus

Introduction- Robot anatomy, types of robots, specifications, work volume, Robot precision movements, end effector, gripper force analysis. Robot applications. Robot kinematics: Representation of rigid body, Transformation, Translation and rotation, homogeneous transformation, Forward and inverse kinematics for position and orientation, DH representation – forward kinematics for articulated joint robots, Problems. Introduction to parallel manipulator – Gough Stewart platform. Forward and inverse kinematics for parallel manipulator. Manipulator Jacobian for serial and parallel manipulator, problem. Singularity analysis. Robot dynamics: Lagrangian formulation, Newton-Euler formulation, Forward and inverse dynamics of serial manipulator, problem. Trajectory planning: Joint space trajectory - point to point and continuous trajectory planning. Cartesian trajectory planning, Computer simulation, Problems.

Text Books/References:

1. Ghosal, Ashitava. "Robotics: fundamental concepts and analysis". Oxford university press, 2006.
2. Niku, Saeed B. "Introduction to robotics: analysis, control, applications". John Wiley & Sons, 2020.
3. Merlet, Jean-Pierre. "Parallel robots". Springer Science & Business Media, 2006.
4. Craig, John J. "Introduction to robotics: mechanics and control", 3/E. Pearson Education India, 2009.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED706 INTRODUCTION TO NONLINEAR DYNAMICS AND CHAOS 3-0-0-3

Course Objectives:

1. Familiarize with nonlinear dynamics concepts for better understanding of physical systems.
2. Demonstrate analytical and numerical tools to analyze systems with nonlinear effects.

Course Outcomes:

CO	CO Description
CO01	Analyse nonlinear dynamical systems using qualitative (also called geometric) approach.
CO02	Analyse one-dimensional, two-dimensional and multi-dimensional nonlinear systems using analytical and numerical tools.
CO03	Analyse different bifurcations of nonlinear systems, their normal forms and applications.
CO04	Quantify and analyse chaotic systems and detail its applications, especially to mechanical systems.
CO05	Analyse engineering, ecological, electronic, biological and financial systems using tools of nonlinear dynamics.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	3	1	2	3
CO02	3	3	1	2	3
CO03	3	3	1	2	3
CO04	3	3	1	2	3
CO05	3	3	1	2	3

Skills Acquired:

Familiar with analytical methods for the analysis of systems with nonlinearity; Development of computational tools for analyzing dynamical systems;Global understanding of the dynamics of systems with continuous and discontinuous nonlinearity.

Course Syllabus:

Introduction and Motivation - Examples of Nonlinear and Chaotic Systems, definition of dynamical system, state space, vector field and flow; One Dimensional Flows – Flows on the line, fixed points and their stability, linear stability analysis, impossibility of oscillations, bifurcations in one dimensional case, saddle-node, transcritical and pitchfork, flows on the circle, examples. Two Dimensional Flows - Planar linear systems, solving linear systems, eigenvalues and eigen vectors, dynamical classification based on eigenvalues, planar nonlinear systems, phase portraits, linearisation, hyperbolic fixed points and Hartman-Grobman theorem, stable, unstable and centre manifolds, limit cycles, van der pol equation, Poincare-Bendixson theorem, saddle-node, transcritical, pitchfork and Andronov-Hopf bifurcations in planar case. Chaotic Dynamics - One dimensional maps, fixed points and cobwebs, logistic map, bifurcations in iterated maps and chaos, Feigenbaum universality. Three dimensional systems, Poincare sections, quasiperiodicity, routes to chaos. Quantifying chaos - Lyapunov exponents, Kolmogorov Sinai entropy, fractal dimensions. Analytical methods for nonlinear systems - Perturbation method, Secular terms, Lindsted - Poincare method, averaging method, method of multiple scales.

Text Books/References:

1. Steven H. Strogatz, “Nonlinear Dynamics and Chaos”, Reading, Addison-Wesley,2000.
2. Robert C. Hilborn, “Chaos and Nonlinear Dynamics”, Section Edition, Oxford University Press, 2000.
3. Ali Hasan Nayfeh, “Introduction to Perturbation Techniques”, John Wiley, 2011.
4. Morris W. Hirsch, Stephen Smale, and Robert L. Devaney, “Differential Equations, Dynamical Systems and an Introduction to Chaos”, Academic Press, Elsevier, 2012.
5. Lakshmanan M. and Rajashekhar S., “Nonlinear Dynamics”, Springer Verlag, 2003.
6. Robert L. Devaney, “An Introduction to Chaotic Systems”, Second Edition, West View Press, 2003.
7. Edward Ott, “Chaos in Dynamical Systems”, Cambridge University Press, 2002.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED707 **MACHINING DYNAMICS** **2-0-3-3**

Course Objectives:

- Introduce basics of the metal cutting mechanism of metal cutting operations
- Review fundamental concepts of free and forced vibrations
- Introduce basics of modal analysis - analytical and experimental
- Inculcate chatter stability analysis of machine tools by introducing self-excited machine tool vibrations
- Introduce advanced topics of high-performance machining / high-speed machining

Course Outcomes:

Cos	CO Description
CO01	Understand the basics of modeling metal cutting operations and identify various parameters affecting metal cutting processes
CO02	Formulate a mathematical model of a system to study its dynamic characteristics considering natural frequency, damping factors, and mode shapes
CO03	Perform stability analysis using Frequency Response Functions (FRF) and Plots, and Stability Lobe Diagrams (SLD) for turning and milling processes
CO04	Familiarize with various sensors and signal processing methods to monitor and control the machining processes
CO05	Conduct experimental investigations to study the dynamic behavior of metal cutting processes and improve their stability

CO-PO Mapping:

COs	PO1	PO2	PO3	PO4	PO5
CO01	3	2	2	3	1
CO02	3	2	2	3	1
CO03	3	2	2	3	1
CO04	3	2	2	3	1
CO05	3	2	2	3	1

Skills Acquired:

Cutting Force measurement using cutting tool dynamometers; Gain user-level familiarity with machine tool dynamics testing equipment and machining process monitoring equipment; Conduct Modal Analysis; Predict Chatter using Frequency Response Functions; Familiarise with software tools for sensor signature processing.

Course Syllabus:

Machining forces: Systems of cutting tool geometry - ASA, ORS and NRS systems - Cutting force components in turning, milling, and drilling - Construction of Merchant Circle Diagram - Cutting power consumption and specific energy requirement - Analytical models for estimation of cutting forces in orthogonal and oblique cutting – Measurement of cutting forces.

Cutting temperature: Analytical estimation of cutting temperature - Experimental methods - Effect of machining parameters on cutting temperature – Control of cutting temperature and cutting fluid application - Concept of machinability – Failure of cutting tool and tool life - Cutting tool materials – Modelling and Simulation of metal cutting processes.

Modal Analysis: Introduction – Frequency Response Functions (FRF) – FRF measurement techniques – Modal parameter extraction - Modal models- Experimental methods.

Machine tool vibration - Vibration analysis methods - Chatter prediction in machining - Vibration control - Frequency response functions and stability lobe plots for turning / milling processes – Sensor-based monitoring of machining processes using Vibration, Acoustic Emission, and Cutting force sensors.

Machining issues in Advanced machining processes: High-Speed Machining, Thin-wall machining, and High-performance machining - Machining economics and optimization.

Lab Component: Cutting Force / Cutting temperature Measurement, Chip Morphological studies, Tool wear and Tool life studies, Modeling and Simulation of metal cutting processes, Modal analysis, and Modal parameter extraction, optimize machining parameters using stability lobe plots, Process monitoring and control using sensors and signal processing.

Text Books/ References:

1. Stephenson, David A., and John S. Agapiou., “Metal cutting theory and practice”, CRC press, 2016.
2. Schmitz, Tony L., and K. Scott Smith., “Machining dynamics”, Birkhauser, Springer, 2014.
3. Grzesik, Wit. “Advanced machining processes of metallic materials: theory, modelling and applications”. Elsevier, 2008.
4. Fu, Zhi-Fang, and Jimin He., “Modal analysis”, Elsevier, 2001.
5. Yusuf, Altintas., "Manufacturing automation: Metal cutting mechanics, machine tool vibrations, and CNC design." Cambridge UP, Cambridge, UK (2000).
6. Juneja BL., “Fundamentals of metal cutting and machine tools”, New Age International; 2003.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	10	-
Continuous Assessment (Lab)*	40	-
End Semester	-	30

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

21ED708 COMPUTATIONAL FLUID DYNAMICS 2-0-3-3

Course Objectives:

1. To study the basic governing equations and understand the basic properties of CFD.
2. To utilize different discretization techniques and solving methods for improving accuracy.
3. To apply the knowledge while solving real time physical problems using simulation software.

Course Outcomes:

CO	CO Description
CO01	Understand the classification of PDEs, governing equations and basic properties of computational methods.
CO02	Apply finite volume method to solve steady and unsteady diffusion, advection-diffusion problems
CO03	Apply the various discretization methods, solution procedures and turbulence modeling to solve flow and heat transfer problems.
CO04	Apply the knowledge to interpret, solve and analyze engineering flow problems.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	3	2	1	3
CO02	3	3	2	1	3
CO03	3	3	2	1	3
CO04	3	3	2	1	3

Skills Acquired:
Ability to relate any physical problem in computational domain with right boundary conditions; Ability to analyze and interpret the results using CFD tools.

Course Syllabus:

Introduction to CFD, Classification of PDEs Simplifications, Building Blocks of CFD, Mathematical description of fluid flow and heat transfer-Conservation equations for mass, momentum, energy and chemical species-Classification of partial differential equations.

Discretization techniques using finite difference and finite volume formulations. Steady and unsteady one-dimensional heat conduction, One dimensional steady convection and diffusion. Formulations for Convection-Diffusion problems, Upwinding, Explicit, Semi-implicit and Fully Implicit formulations for unsteady problems, Stability analysis. The concept of false diffusion, QUICK scheme, TVD schemes and flux limiter functions.

Discretization of Navier Stokes Equations, primitive variable approach, SIMPLE Algorithm, SIMPLER Algorithm, Unstructured Grid Formulation, Introduction to Turbulence Modeling, spray and combustion modeling, Adaptive mesh refinement, Applications to practical problems using OpenFoam/PyCFD and other commercial softwares.

Text Books/References:

1. Versteeg, H.K., and Malalasekara, W, "An Introduction to Computational Fluid Dynamics", The Finite Volume Method, 2007
2. Moukalled, F., Mangani, L., and Darwish, M. "The finite volume method in computational fluid dynamics. An Advanced Introduction with OpenFOAM and Matlab", 2016.
3. Patankar, S.V., "Numerical Heat Transfer and Fluid Flow", Hemisphere Publishing Corporation, 1980.
4. Anderson, D.A., Tannehill J.C., and Pletcher, R.H., "Computational Fluid Mechanics and Heat Transfer", Hemisphere Publishing Corporation, 1984

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	10	-
Continuous Assessment (Lab)*	40	-
End Semester	-	30

1.

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

21ED709 THEORY OF PLATES AND SHELLS 3-0-0-3

Course Objectives:

1. Familiarize the concept of plate and study the behaviour of rectangular and circular plates.
2. Familiarize the concept of shells and study the classification of shell surfaces.
3. Inculcate the knowledge to formulate and solve classical plate and shell theory based problems in the area of structural mechanics.
4. Demonstrate numerical and analytic problem-solving methods.

Course Outcomes:

CO	CO Description
CO1	Analyze rectangular plates to solve for stresses, moments and deflections utilizing classical, special and approximate methods
CO2	Analyze circular plates under axi-symmetric deflection
CO3	Analyze plates on elastic foundation
CO4	Classify different types of shells and solve for their deformed shapes and stresses using membrane theory

CO-PO Mapping:

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2	2	2
CO2	3	3	2	2	1
CO3	3	3	2	2	1
CO4	3	3	2	2	2

Skills Acquired:

Develop analytical models based on classical theory of plates and shells to formulate and solve elastic problems in the area of structural mechanics, using material constitutive laws, compatibility conditions, and governing equations, and also to analyze stresses, moments and deflections in continua under varying loading conditions.

Course Syllabus:

Introduction - Formulation of governing equations and associated boundary conditions by equilibrium and energy methods, Rectangular plates - Solution of equation by double and single series, Circular plates - symmetric and un-symmetric loading cases, Continuous Plates, Plates with various plan forms, Plates with variable flexural rigidity, Plates on elastic foundation. Numerical and approximate methods - finite difference method - finite element method, energy methods and other variational methods. Introduction, Theory of Surfaces - first and second fundamental forms - principal curvatures, Formulation of governing equations in general orthogonal curvilinear coordinates based on classical assumptions - various shell theories, Membrane theory - governing equations - shells of revolution - application to specific geometric shapes - axisymmetric and non-axisymmetric loading cases. General theory of shells - governing equations and associated boundary conditions for specific geometry of shells (cylindrical, conical and spherical shells) - classical solutions - finite difference and finite element methods applied to shell problems.

Text Books/References:

1. Vardhan T. K. and Bhaskar K., “Analysis of Plates: Theory and Problems”, John Wiley & Sons, 1999.
2. Timoshenko S. and Woinowsky Krieger S., “Theory of Plates and Shells”, McGraw-Hill, 2017.
3. Chandrashekhara K., “Theory of Plates”, Universities Press, 2001.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED710 MECHANICS OF COMPOSITE MATERIALS 3-0-0-3

Course Objectives:

1. Understand the significance of composite materials and different manufacturing methodologies.

2. Introduce technological properties of the advanced materials with the conventional materials.
3. Perform the analysis of composite materials using strength of materials and elasticity based approach.

Course Outcomes:

CO	CO Description
CO1	Classify and Understand different types of fibers and matrix
CO2	Familiarize with different manufacturing processes, testing and recycling methods.
CO3	Apply Hooke’s law in the micromechanical analysis of Laminae and Laminate
CO4	Analyze various types of structural composites subjected to different types of loading conditions.

CO-PO MAPPING:

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2	2	2
CO2	3	3	2	2	3
CO3	3	3	2	3	3
CO4	3	3	2	3	3

Skills Acquired:

Composite manufacturing skills like gluing, carbon and composite cloth handling. Know-how in vacuum and heat treatment techniques for curing of repairs and NDT skills to verify repairs will be acquired as well. Developing analytical models based on continuum theory to formulate and solve problems in the area of structures by applying damage criterions and constitutive laws, compatibility conditions, and governing equations, and also to analyze stresses and strains, stiffnesses of symmetric and asymmetric laminates.

Course Syllabus:

Introduction: Definitions, Composites, Reinforcements and matrices, Types of reinforcements, Types of matrices, Types of composites, Carbon Fiber composites, Properties of composites in comparison with standard materials, Applications of metal ceramic and polymer matrix composites. Manufacturing methods: Hand and spray lay - up, injection molding, resin injection, filament winding, pultrusion, centrifugal casting and prepregs. Fiber/Matrix Interface, mechanical. Measurement of interface strength. Characterization of systems; carbon fiber/epoxy, glass fiber/polyester, Testing of Composites etc. Characterizations of Composite-Non-Destructive testing on Composites- Joining -Advantages and disadvantages of adhesive and mechanically fastened joints. Typical bond strengths and test procedures. Recycling of Composites –Primary and Secondary Recycling of Composites.

Analysis of an orthotropic lamina-Analysis of laminated composites-Fracture mechanics-Determination of strain energy release rate-Stress analysis - interlaminar stresses and free edge effects-Failure Criteria-Whitness Nuismer failure criteria-Vibration and stability analysis- Introduction to Design of Composite Structures –Introduction to Structural -Design and Analysis of mechanically fastened joints- Optimization Concepts–Fatigue in Composites-Effects of holes in Laminates –Transverse shear effects-Post curing shapes of Unsymmetric Laminates- Case studies Application of finite element methods applied to polymer composite modeling with micro and nano fillers particular to structural applications.

Text Books/References:

1. Mallick P. K., "Fiber Reinforced Composite Materials - Manufacturing and Design", Marcel Dekker, 2008.
2. Robert M. Jones, "Mechanics of Composite Materials", Second Edition, Taylor and Francis, 1999.
3. Halpin J. C., "Primer on Composite Materials Analysis", Techomic, 1992.
4. Mallick P. K. and Newman S., "Composite Materials Technology - Processes and Properties", Hansen, 1991.
5. Agarwal B. D. and Broutmen L. J., "Analysis and Performance of Fibre Composites", John Wiley & Sons, 2017.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED711 FRACTURE MECHANICS 3-0-0-3

Course Objectives:

1. Understand effect of defects on the performance of engineering systems and components.

2. Predict the state of structures with crack using LEFM and estimate energy release rate, stress intensity factor and J-integral.
3.Understand the procedure for testing fracture parameters and fatigue life according to standards.

Course Outcomes:

CO	CO Description
CO01	Apply principles of elasticity and linear elastic fracture mechanics to solve for stress intensity factor and energy release rate of structures with cracks.
CO02	Formulate J-integral and analyze stress-strain fields around a crack tip for non-linear material behavior.
CO03	Estimate fatigue crack growth using principles of fracture mechanics.
CO04	Predict stress intensity factor, energy release rate and J-integral, computationally, as per ASTM standards.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	-	1
CO02	3	2	1	-	2
CO03	3	2	1	-	2
CO04	2	3	2	1	2

Skills Acquired:

Calculate fracture mechanics parameters like energy release rate, stress intensity factor, crack opening displacement, J-integral etc and service life of components based on fatigue and fatigue crack propagation using analytical and computational techniques.

Course Syllabus:

Introduction and review of solid mechanics, plane elasticity- In-plane and out-of-plane problems-Airy's stress function-plate with a circular hole, elliptic hole. Fatigue-Failure of uncracked solids, stress-life approach, strain-life approach, Effect of mean stress, Miner's rule, Damage rule for irregular loads. Linear Elastic Fracture mechanics: Energetics of fracture, Griffith's energy balance, strain energy release rate, stability of crack growth-R curve, Eigen expansion for wedges and notches, stress ,displacement field at the crack tip for Mode I and Mode II, Stress Intensity Factor (SIF), Mode III fields, Westergaards function, Relationship between K and G, direction of crack propagation, mixed mode fracture, SIF for various geometries, Crack-Tip plasticity, Correction factor for plasticity effects, Experimental determination of Kc. Elastic-Plastic Fracture mechanics: J- contour integral, Relation between J-integral and CTOD, crack growth resistance curves, constraint effect in fracture, Experimental measurement of J integral. Fatigue - Growth of an initial crack, Fatigue crack growth analysis, Paris law, fatigue life, variable amplitude loading. Fracture mechanics in metals: Ductile fracture, cleavage fracture, ductile-brittle transition.

Text Books/References:

1. Anderson T. L., "Fracture Mechanics: Fundamentals and Applications", Third Edition, CRC Press, 2005.
2. Suresh S., "Fatigue of Materials", Second Edition, Cambridge University Press, 2012.
3. Barsom J. M. and Roffe S. T., "Fracture and Fatigue Control in Structures", Third Edition, Englewoods Cliffs, Prentice Hall, 1999.
4. Broek D., "Elementary Engineering Fracture Mechanics", Fourth Edition, Martinus Nijhoff, 1987.
5. Knott J. K., "Fundamentals of Fracture Mechanics", Third Edition, Butterworth Heinemann, 2011.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED712 TRIBOLOGY 3-0-0-3

Course Objectives

1. To inculcate the knowledge in modern theories of friction and lubrication to predict about frictional behvaiour
2. To characterize the features of engineering surfaces and analyse its topography and surface roughness
3. To explore the factors influencing the selection of bearing materials for different sliding applications

Course Outcomes:

CO	CO Description
CO1	To understand the concepts of tribology and its related theories for performance analysis
CO2	Analyse the requirements and select proper bearing materials and lubricants for a specific application
CO3	To apply the principles of engineering surfaces for various tribological applications
CO4	To understand the principles of hydrodynamic lubrication and its design consideration in journal and thrust bearings

CO-PO Mapping:

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2	2	0
CO2	3	3	0	2	0
CO3	3	3	2	2	1
CO4	3	3	0	2	0

Skills acquired:

Developing an understand of engineering surfaces and its associated wear mechanisms.Also, acquiring the knowledge required to understand and apply various mechanisms of lubrication and its related bearing materials for various tribological applications

Course Syllabus:

Engineering Surfaces - surface topography-Analysis of surface roughness-Conformal and non-conformal surfaces-Greenwood and Williamson Model-Contact mechanics, Dry contacts-Friction, Modern theories of friction-Stick-Slip Phenomenon-Liquid-Mediated contacts-Wear, Effect of surface roughness, friction, and sliding speed on wear-Ferrography - Oil Analysis Program - Basic equations of Flow, Navier-Stokes equation, Generalized Reynolds's equation-Hydrodynamic lubrication-Boundary lubrication-Bearing materials-Hydrodynamic real (finite) bearings-Design considerations in journal and thrust bearings-Hydrodynamic instability-Hydrodynamic and hydrostatic gas bearings-Idealized slider and journal bearings-Oil flow and Thermal analysis of bearings-Bearing selection and design-Dynamically loaded bearings-Squeeze film bearings.

Text Books/References:

1. Majumdar B. C., "Tribology of Bearings", S. Chand & Company Ltd., 2008.

2. Bharat Bhushan, “Introduction to Tribology”, John Wiley & Sons, 2013.
3. Moore and Desmond. F., “Principles and Applications of Tribology”, Pergamom Press, 1975.
4. Dudley D. Fuller, “Theory and Practice of Lubrication for Engineers”, John Wiley & Sons, 1984.
5. Johnson K. L., “Contact Mechanics”, Cambridge University Press, 1987.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED713 DESIGN FOR MANUFACTURE AND ASSEMBLY 3-0-0-3

Course Objectives:

1. Understand the concept and application for Design for manufacturing and assembly and its impact on product cost and quality.
2. Be able to optimize tolerances to enhance manufacturability.
3. Be able to optimize various manufacturing processes to enhance manufacturability.
4. Be able to discuss various fundamentals of assembly and design recommendations for product development.

Course Outcomes:

CO	CO Description
CO01	Understand the Design fundamentals, material selection process and compare the cost implications of the Design and manufacturability of various products.
CO02	Apply design guidelines for manufacturing processes like casting, welding, forming machining and powder metallurgy.
CO03	To Understand and Evaluate the Environmental impacts due to the implementation DFMA in various processes.
CO04	Analyze any product and Improve upon the existing ones using the DFMA guidelines and principles.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	3	1
CO02	3	2	1	3	1
CO03	3	2	1	3	1
CO04	3	2	1	3	1

Skills Acquired:

Design a new product with reduced manufacturing & Assembly time, and cost. Analyse existing product/ manufacturing processes and provide design recommendations.

Course Syllabus:

Introduction to DFMA, DFA guidelines,

Group technology, Value engineering, Geometric Dimensioning and Tolerancing,

Introduction to materials and material selection: Classification of engineering materials, Material selection for product design

Classification of the manufacturing process, Basic manufacturing processes, Mechanical properties of the material

Design for Casting- Introduction to casting - Sand casting, Die-casting, Injection moulding - Design recommendation, suitable materials

Design for powder metal processing: Introduction to powder metal processing, Design recommendations.

Design for machining: Introduction to machining - Design for tuning operation, Design for machining round holes, Design for milling Process, Design for broached parts – Process description, Suitable materials, Design recommendations, Recommended tolerances

Metal Extrusion: Introduction to Metal Extrusion Process – Metal stamping, Rolled formed section, Design for extrusion, Design for Forging - Suitable Material, Design Recommendations

Design for welding: Design for the recommendation for welding process, Design for solder and brazed assembly, Design for adhesively bonded constructions - Suitable materials, Design recommendations

Design for Assembly: Introduction, Design consideration, Design for Fasteners: Introduction, Design recommendation for fasteners.

Environmental objectives – Global issues – Regional and local issues – Lifecycle Assessment – Techniques to reduce environmental impact – Design to minimize material usage – Design for disassembly – Design for recyclability – Design for remanufacturing – Design for energy efficiency – Design to regulations and standards.

Text Books and References:

1. Geoffrey Boothroyd, Peter Dewhurst and Winston Knight (2010) Product Design for Manufacture and Assembly, Third Edition, CRC Press, Taylor & Francis, Florida, USA
2. James G.Bralla (1998) Design for Manufacturability Handbook, Second Edition, McGraw-Hill Companies, New York, USA
3. George E. Dieter and Linda C.Schmidt (2009), Engineering Design, Fourth Edition, McGraw-Hill Companies, New York, USA

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED714 SELECTION OF MATERIALS AND PRODUCT DESIGN 2-0-3-3

Course Objectives:

1. To train each participant in design-oriented materials selection.
2. To ensure quality and performance of engineering design processes and product development.
3. To understand various product development tools and methods used in engineering design process

Course Outcomes:

CO	CO Description
CO01	Understand design-oriented materials selection for different engineering applications
CO02	Identify, analyze and synthesize all the stakeholders' needs and customer requirements
CO03	Use various product development tools and methods to propose conceptual model
CO04	Provide solution for sustainable product design

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	0	0	1
CO02	3	2	0	2	2
CO03	3	2	1	3	2
CO04	3	2	3	3	3

Skills acquired:

Conceive and develop product designs with appropriate choice of materials diversified applications.

Course Syllabus:

SELECTION OF MATERIALS: Selection for mechanical properties: strength, toughness, stiffness, fatigue, creep resistance, wear resistance, relationship between material selection and material processing, material life cycle, selecting materials for eco-design

DESIGN PROCESS: Strategic design, matching materials to design, stiffness limited design, strength limited design, fracture limited design, standard solutions to elastic problems, manipulating strength, material saving by form design, Design case studies

PRODUCT DESIGN: Stakeholder requirements, functional modelling, Conceptual Design: Generation, selection and embodiment of concept, Testing & Prototyping, Morphology of design, Product Architecture, Modularity and platform, Product life cycle, Product cost analysis, Innovative thinking, sustainability, Product Design case studies

TEAM PROJECT

Text Books/References:

1. J.A.Charles, F.A.A Crane, J.A.G, Furness, "Selection and use of Engineering Materials", Butterworth Heinemann, 1997.

2. Michael Ashby, Hugh Shercliff, David Cebon, “Materials: Engineering Science Processing and Design”, Butterworth Heinemann,2013.
3. Shigley and Mische, “Mechanical Engineering Design”, McGraw Hill, Inc., New Delhi, 2003.
4. Myer Kutz, “Environmentally Conscious Mechanical Design”, Wiley, 2007.
5. Ulrich, K. T., & Eppinger, S. D, “Product Design and Development” (Vol. Third edit). McGraw-Hill, 2004
6. Pruitt, J., & Adlin, T, “The Persona Lifecycle: Keeping People in Mind Throughout Product Design” . (E. Inc., Ed.). Morgan Kaufmann, 2006.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	10	-
Continuous Assessment (Lab)*	40	-
End Semester	-	30

2.

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

21ED715 DESIGN THINKING 2-0-3-3

Course Objectives:

1. To introduce to the students the concept of design thinking
2. To make the students as a good designer by imparting creativity and problem solving ability

Course Outcomes:

CO	CO Description
CO01	Students will be able to understand the diverse methods employed in design thinking and establish a workable design thinking framework to use in their practices
CO02	Students will be able to examine critical theories of design, systems thinking, and design methodologies.
CO03	Students will be able to produce great designs, be a more effective engineer, and communicate with high emotional and intellectual impact
CO04	Students will be able to conceive, organize, lead and implement projects in interdisciplinary domain and address social concerns with innovative approaches

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	3	0	2	3
CO02	3	3	0	2	3
CO03	3	3	2	0	3
CO04	3	3	2	2	3

Skills acquired:

Understand the customer need with better clarity, develop product design concepts with innovative ideas and develop prototypes

Course Syllabus:

Design process: Traditional design, Design thinking, Existing sample design projects, Study on designs around us, Compositions/structure of a design,

Innovative design: Breaking of patterns, Reframe existing design problems, Principles of creativity

Empathy: Customer Needs, Insight-leaving from the lives of others/standing on the shoes of others, Observation

Design team-Team formation, Conceptualization: Visual thinking, Drawing/sketching, New concept thinking, Patents and Intellectual Property, Concept Generation Methodologies, Concept Selection, Concept Testing, Opportunity identification

Prototyping: Principles of prototyping, Prototyping technologies, Prototype using simple things, Wooden model, Clay model, 3D printing; Experimenting/testing.

Sustainable product design, Ergonomics, Semantics, Entrepreneurship/business ideas, Branding, Advertising.

Product Data Specification, Establishing target specifications, Setting the final specifications.

Design projects for teams.

Text Books/References:

1. Tim Brown, “Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation”, HarperCollins Publishers Ltd,2019.
2. Idris Mootee, “Design Thinking for Strategic Innovation”, John Wiley & Sons Inc., 2013.
3. Brenda Laurel, “Design Research methods and perspectives” MIT press 2003
4. Terwiesch, C. & Ulrich, K.T., “Innovation Tournaments: creating and identifying Exceptional Opportunities”, Harvard business press, 2009.
5. Ulrich & Eppinger, “Product Design and Development”, 3rd Edition, McGraw Hill, 2004
6. Stuart Pugh, “Total Design: Integrated Methods for Successful Product Engineering”, Addison-Wesley, 1991.
7. Bjarki Hallgrimsson, “Prototyping and model making for product design”, Laurence King Publishing Ltd, 2012.
8. Kevin Henry, “Drawing for Product designers”, Laurence King Publishing Ltd,2012.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	10	-
Continuous Assessment (Lab)*	40	-
End Semester	-	30

3.

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

21ED716 ENGINEERING DESIGN-PRODUCT ARCHITECT 2-0-3-3

Course Objectives:

- To develop competencies of masters students in Engineering to carry Product Architect jobs.
- To impart strong technical skill and holistic vision of product design flow
- To introduce design and product development tools and methods used in engineering design

- To ensure quality and performance of engineering design processes and product development.

Course Outcomes:

CO	CO Description
CO01	identify, analyze and synthesize all the stakeholders' needs and customer requirements
CO02	Design the product / system architecture in collaboration with the others and allocate each functions into different sub-system.
CO03	Ensure a consistent set of requirement taking into account the global vision of reduced cost of product design
CO04	Ensure the transfer of all data to the Project internal contributor and external supplier and ensure the interface with the customer.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	2	1	0	0	2
CO02	2	1	1	1	2
CO03	2	1	0	0	2
CO04	2	1	0	0	2

Skills acquired:

Understand the customer need, develop function requirement for the product with manufacturing feasibility using a system engineering approach

Course Syllabus:

Introduction to Product design and development process. Stakeholder Requirements and specification-User Product requirements formalization, Functional elicitation and modeling, QFD and Market segmentation. Product architecture - modularity and platform, Architecture definition, Design Structured Matrix (product) and Function allocation. Manufacturing issues - Manufacturing flow, Assembly cost estimation, Design for assembly basics and Supplier management. Design to cost - product cost analysis and value analysis. Product design processes organization and performance- project organization, Lean product development and System Engineering

Text Books/References:

1. Mital, A, "Product development : a structured approach to consumer product development, design, and manufacture". Amsterdam ; Boston, MA: Butterworth-Henemann,2008
2. Ulrich, K. T., & Eppinger, S. D, "Product Design and Development", McGraw-Hill, 2004.

3. Whitney, D. E., “Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development”, Oxford: Oxford University Press, 2004
4. Pahl, G., Beitz, W., Wallace, K., Blessing, L., & Bauert, F, “Engineering design a systematic approach”, second edition Springer, 1996
5. Brown, T, “Design Thinking”,Harvard Business Review, 2008.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	10	-
Continuous Assessment (Lab)*	40	-
End Semester	-	30

4.

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

21ED717 DESIGN FOR ADDITIVE MANUFACTURING 3-0-0-3

Course Objectives:

1. Impart the knowledge of additive manufacturing technologies and their importance in industry 4.0

2. Enable the student to understand, evaluate, analyze strategic design considerations for additive manufacturing, part consolidation and software tools
3. Familiarize the student on design and guidelines for polymer, metal additive manufacturing techniques and post-processing considerations

Course Outcomes to:

Cos	CO Description
CO01	Inculcate working principle of metal and polymer additive manufacturing technologies
CO02	Understand the computational tools for design, analysis and optimization of AM parts
CO03	Impart a basic understanding of the DfAM strategic design considerations and part consolidation
CO04	Ensure the students to design and use guidelines for polymer and metal AM techniques

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	2	0
CO02	3	2	0	2	3
CO03	3	2	0	2	0
CO04	3	2	0	2	1

Skills Acquired:

Ability to select the appropriate additive manufacturing technologies to design complex shapes and production parts at reducing weight and material consumption.

Course Syllabus:

Introduction to Additive Manufacturing and Its Techniques

Introduction to Additive Manufacturing (AM), Generic steps in additive manufacturing, process chain, Types of Additive Manufacturing technologies; Binder Jetting, Directed Energy Deposition, Material Extrusion, Material Jetting, Powder Bed Fusion, Sheet Lamination, and Vat Photopolymerization, Materials, Applications, Advantages and Disadvantages of Various processes

DfAM Strategic Design Considerations and Computational Tools for AM Parts

Introduction to Design for Additive Manufacturing, General Guidelines for Designing AM parts, Design to avoid Anisotropy, Economics of Additive Manufacturing, Design to minimize print time, Design to minimize post-processing, Advantage of Design Complexity

Aims of using design analysis for AM, Topology Optimization-Objective and Constraints, Common settings, Post-Processing and Interpreting results, Parametric or Size Optimization, Build process simulation-Layer by Layer Simulation, Scan pattern simulation, Limitations, Distortion modelling,

Design and Guidelines of AM Technologies

Design for Polymer AM- Anisotropy, Wall thickness, Overhangs, and Supports, Design for Metal AM-Designing for Metal Powder Bed Fusion, Powder Morphology, Powder handling & power recycling, Potential defects in AM, Balling defects, Lattice Structures, Residual Stress, Stress Concentrations, Post- processing-heat treatment, HIPS, shot peening, etc.,

Text Books/References:

1. Martin L, “Design for Additive Manufacturing.” Elsevier Science, 2019.
2. Olaf Diegel, Axel Nordin, Damien Motte, ‘A Practical Guide to Design for Additive Manufacturing’ Springer, 2019.
3. Gibson I, Rosen D, Stucker B “Additive manufacturing technologies: 3D printing, rapid prototyping, and direct digital manufacturing.” 2nd edition. Springer, Berlin, 2015.
4. T.S. Srivatsan, T.S, “Sudarshan Additive Manufacturing Innovations, Advances, and Applications.” CRC Press, 2016

Evaluation Pattern

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED718 MULTI OBJECTIVE OPTIMIZATION 2-0-3-3

Course Objectives:

1. Introduce the classical and evolutionary methods of optimization techniques used for solving engineering optimization problems with multiple objectives.
2. Considering the computational aspects, the course will involve a significant number of computational assignments using software tools and a term project focusing on solving multi-objective optimization problems in design and manufacturing fields.

Course Outcomes:

COs	CO Description
CO01	Formulate Engineering problem as a multi-objective optimization problem
CO02	Apply evolutionary optimization techniques to solve complex Engineering problems involving multiple objectives using classical optimization approaches
CO03	Appreciate the concepts of Pareto optimality and generate non-dominated solutions using evolutionary algorithms for solving multi-objective optimization problems
CO04	Formulate and solve real-world MOOPs in Engineering Design / Manufacturing fields using Evolutionary Multi-Objective approaches and generate non-dominant solutions using software tools

CO-PO Mapping:

COs	PO1	PO2	PO3	PO4	PO5
CO01	3	2	2	2	2
CO02	3	2	2	2	2
CO03	3	2	2	2	2
CO04	3	2	2	2	2

Skills Acquired:

Formulate Engineering problem as a multi-objective optimization problem; Solve multi objective optimization problems using traditional and evolutionary muti- objective optimization algorithm; Generate solutions for muti-objective optimization problems using software tools.

Course Syllabus:

Problem Formulation: System characterization - Identification of objectives, design variables, constraints, subsystems - System-level coupling and interactions - Examples of Multi-Objective Optimization (MOO) Problems in practice - Visualization techniques in design optimization.

Optimization and Search Methods: Optimization and exploration techniques: Review of linear and nonlinear programming - Heuristic techniques: Genetic Algorithms (GA), Simulated Annealing (SA), Particle Swarm Optimization (PSO) – Constraint handling method for heuristic algorithms - Design Space Exploration.

Classical methods for MOO: weighted sum approach - ε constraint method – Goal Programming method.

Multi-Objective Optimization Problem: Principles of MOO – Dominance and Pareto Optimality – Optimality Conditions.

Evolutionary MOO approaches Non-Elitist Multi-Objective GA – Elitist Multi-Objective GA – Non-Dominated Sorting GA – Multi-Objective PSO algorithms - Representation of non-dominant solutions – Convergence issues.

Lab Practice:

- Solving multi-objective optimization problems using classical optimization approach (Goal programming / Weighted sum approach)
- Solving multi-objective optimization problems using evolutionary methods (NSGA-II / PSO based approach)
- Applications of Multi-Objective Evolutionary algorithms: Case Study - Mechanical Component Design – Shape, topology, and trajectory optimization – Implementation of MOO algorithms to solve real-world applications using software tools.

Text Books/ References:

1. Deb, Kalyanmoy, "Multi-objective optimization using evolutionary algorithms", Vol. 16. John Wiley & Sons, 2011.
2. Coello, Carlos A. Coello, Gary B. Lamont, and David A. Van Veldhuizen.,"Evolutionary algorithms for solving multi-objective problems". Vol. 5. New York: Springer, 2007.
3. Bechikh, Slim, Rituparna Datta, and Abhishek Gupta., "Recent Advances in Evolutionary Multi-objective Optimization." Springer 2018.
4. Mirjalili, Seyedali, and Jin Song Dong. "Multi-objective optimization using artificial intelligence techniques". Springer, 2020.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	10	-
Periodical 2	10	-
Continuous Assessment (Theory)*	10	-
Continuous Assessment (Lab)*	40	-
End Semester	-	30

5.

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

21ED719 **ROBUST DESIGN** **3-0-0-3**

Course Objectives:

1. The course presents the theory of modeling with a variation using physical models and methods for practical applications on designs more insensitive to variation.
2. Provides a comprehensive understanding of optimization and robustness for probabilistic design

Course Outcomes:

COs	CO Description
CO01	Familiarize with the statistical theories required for implementing robust design concepts in product development
CO02	Create designs that have minimal sensitivity to input variation
CO03	Perform sensitivity analysis and determine design parameters that have the largest impact on variation
CO04	Optimize design with multiple outputs
CO05	Create Empirical models to estimate system outputs

CO-PO Mapping:

COs	PO1	PO2	PO3	PO4	PO5
CO01	3	2	3	2	1
CO02	3	2	3	2	1
CO03	3	2	3	2	1
CO04	3	2	3	2	1
CO05	3	2	3	2	1

Skills Acquired:

Perform sensitivity analysis and determine design parameters that have the largest impact on variation; Conduct Tolerance Analysis; Develop Empirical models to estimate system outputs.

Syllabus:

New product development process: Phases, Patterns, Design for Six Sigma – Statistical background for new product design: Statistical distributions, Probability plotting – Process capability – Robustness Concept

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: Requirements and scorecards, determining desirability.

Optimization and sensitivity: Optimization procedure, Statistical outliers, Process capability, Sensitivity, and cost reduction – Modelling system cost and multiple outputs - Case studies and problem-solving - Tolerance analysis: Tolerance analysis methods, Tolerance allocation, Drift, Shift and Sorting – Case Studies and problem-solving

Empirical Modelling: Screening, Response Surfaces, Central Composite Design, Taguchi approach – Logistic regression and customer loss function – Case studies - Engineering model verification and validation: Introduction, Design verification methods, and tools, Process validation procedure, Case study and Problem-solving using software tools.

Text Books/ References:

1. Dodson, Bryan, Patrick C. Hammett, and Rene Klerx. "Probabilistic design for optimization and robustness for engineers". Hoboken, NJ: Wiley, 2014.
2. Arner, Magnus., "Statistical robust design",Wiley, 2014.
3. Roy, Ranjit K., "Design of experiments using the Taguchi approach: 16 steps to product and process improvement"., John Wiley & Sons, 2001.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

21ED720 MACHINE CONDITION MONITORING 3-0-0-3

Course Objectives:

- Familiarize with the concept of condition-based maintenance for effective utilization of machines
- Impart knowledge of prognosis for estimation of remaining useful life.

Course Outcomes:

CO	CO Description
CO01	Select the proper maintenance strategies and condition monitoring techniques for identification of failure in a machine.
CO02	Acquire and Process sound and vibration signals in a dynamic mechanical system
CO03	Predict the faulty component in a machine by analyzing the acquired vibration signals
CO04	Estimate the remaining useful life of the faulty component.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	3	2
CO02	3	2	1	3	2
CO03	3	2	1	3	2
CO04	3	2	1	3	2

Skills Acquired:

Choose the proper condition monitoring techniques; Analysis of vibration signals for prediction of faulty component; Estimate the remaining useful life of the component using prognostic models.

Course Syllabus:

Introduction and Background: Condition Monitoring Methods, Vibration Measurement and Analysis, Benefits of Vibration Analysis, Vibration Transducers, Vibration Signals from Rotating Machines, Infrared Thermography, Oil Analysis and Tribology, Ultrasonics, Motor Current Analysis.

Signals and systems: Introduction to signal processing, sampling and aliasing, Nyquist sampling theorem, analog to digital conversion, Fourier transform and Fourier series, discrete Fourier transform, properties, fast Fourier transform, Filtering: FIR and IIR filters Implementation.

Overview of wavelet transform: Continuous wavelet transform, discrete wavelet transform, wavelet packets, Applications in denoising and feature extraction.

Condition monitoring of gearboxes, Condition Monitoring of ball/roller bearings, Condition monitoring in IC Engines, Condition monitoring in electrical machines, Monitoring and Control of Machining, Precision Manufacturing Process Monitoring with Acoustic Emission, Tool Condition Monitoring.

Fault-Trending and Prognostics: Trend Analysis, Advanced Prognostics, Data-Driven Models and Hybrid Models.

Text Books and References:

1. Robert Bond Randall, "Vibration-Based Condition Monitoring: Industrial, Aerospace and Automotive Applications", John Wiley & Sons, 2011.
2. George Vachtsevanos, Frank L. Lewis, Michael Roemer, Andrew Hessand Biqing Wu., "Intelligent Fault Diagnosis and Prognosis for Engineering Systems", Wiley, 2006.
3. John G. Proakis and Dimitris G. Manolakis, "Digital Signal Processing Principles, Algorithms, Applications", Fourth Edition, PHI, 2007.
4. Stephane Mallat, "A Wavelet Tour of Signal Processing: The Sparse Way", Third Edition, Academic Press, 2009.
5. Kihong Shin and Joseph K. Hammond, "Fundamentals of Signal Processing for Sound and Vibration Engineers", John Wiley & Sons Ltd., 2008.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED721 **RELIABILITY ENGINEERING** **3-0-0-3**

Course Objective:

Provide the importance of reliability, the basic methods to evaluate product and system reliability

Course Outcomes:

CO	CO Description
CO01	Determine the reliability of a product by applying the knowledge of probabilistic concept.
CO02	Identify and select the various failure models
CO03	Identify and select different reliability testing methods
CO04	Predict the reliability of a product using failure data.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5
CO01	3	2	1	2	-
CO02	3	2	1	2	-
CO03	3	2	1	2	-
CO04	3	2	1	2	-

Skills Acquired:

Ability to determine reliability of a system and to identify suitable testing methods for industrial applications

Course Syllabus:

Concept and Definition of reliability (reliability mathematics)-Failure distributions, hazard models – exponential, Rayleigh, Weibull, Normal and Lognormal distributions -MTTF, MTBF. Reliability of systems – series and parallel configurations - Reliability improvement, redundancy, k-out-of-n system -Reliability of complex configurations-Reliability of three-state devices – Markov analysis-Physical reliability models – random stress and random strength-Design for reliability-Reliability allocation, derating-Maintainability-Design for maintainability-Availability-Maintenance and space provisioning. Failure data analysis-Reliability Testing-Identifying failure distributions– parameter estimation.

Approaches to intelligent control- AI approach- Concept of artificial neural network and its model, fuzzy logic and its model- Case study

Text Books/ References:

1. Charles Ebeling, "An introduction to Reliability and Maintainability Engineering", Tata McGraw Hill, 2000.
2. Lewis E. E., "Introduction to Reliability Engineering", Second Edition, John Wiley & Sons, 1995.
3. Rao S. S., "Reliability Based Design", McGraw Hill, 1992.
4. Srinath L.S., "Mechanical Reliability", East-West Press,2002.
5. Simon Haykins, "Neural network : A comprehensive foundation", Pearson Edition,2003
6. T. J. Ross, "Fuzzy logic with fuzzy application",McGrawHill, 1997.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc

21ED722 MECHATRONIC SYSTEM DESIGN 3-0-0-3

Course Objectives:

1. To Impart knowledge on the concept of system simulation and design
2. To give the exposure on mechatronics products and applications of IOT

Course Outcomes:

COs	CO Description
CO01	Apply the concept of Mechatronics system design approach to design the process
CO02	Perform the real time interface with physical systems, sensors, and actuators
CO03	Apply the modelling and simulation concepts and analyse the results
CO04	Apply the concepts of IOT, AI, and Machine learning algorithms to design the mechatronics products

CO-PO Mapping:

COs	PO1	PO2	PO3	PO4	PO5
CO01	3	2	2	2	1
CO02	3	2	1	0	2
CO03	3	2	2	2	2
CO04	3	2	2	0	2

Skills acquired:

Design the Mechatronics products through modelling, simulation, and able to analyse the products and also able to apply the principle of automation in the required field via real time interfacing.

Course Syllabus:

Mechatronic systems, Mechatronic design process, Traditional and Mechatronics designs, Advanced approaches in Mechatronics system, Industrial design and ergonomics. Real-time interfacing, Elements of data acquisition and control, Overview of I/O process, Analog signals, discrete signals and Frequency signals. Simulation basics, Probability concepts in simulation, Discrete event simulation, Simulation Methodology, Queuing system model components, Continuous system modelling, Monte Carlo simulation, Analysis of simulation results, Simulation life cycle. Case studies of design of mechatronic products: Motion control using DC Motor & Solenoids, Car engine management systems. Applications in Mechatronics: Sensors for condition based maintenance, Mechatronic Control in IoT based system, Artificial intelligence in Mechatronics, Machine Learning Applications in Mechatronics.

Text Books/ References:

1. Bolton, “Mechatronics – Electronic control systems in mechanical and electrical engineering, 2nd edition, Addison Wesley Longman Ltd., 2009.
2. Bishop, Robert H. Mechatronics: an introduction. CRC Press, 2017.
3. Brian morriss, “Automated manufacturing Systems – Actuators Controls, sensors and Robotics”, McGraw Hill International Edition, 2000.
4. Bradley, D. Dawson, N.C.Burd and A.J. Loader, “Mechatronics: Electronics in product and process”, Chapman and Hall, London, 1999.
5. Klaus Janschek, “Mechatronic Systems Design”, Springer publisher, 2012.

Evaluation Pattern:

Evaluation Components	Internal	External
Periodical 1	15	-
Periodical 2	15	-
Continuous Assessment *	20	-
End Semester	-	50

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc