M.TECH PROGRAMME

ENGINEERING DESIGN

CURRICULUM & SYLLABUS

DEPARTMENT OF MECHANICAL ENGINEERING

2024 Admission onwards

M. Tech Engineering Design

Department of Mechanical Engineering

Program Introduction

The M.Tech Engineering Design is a two-year program designed to enable an engineering student to develop specific capabilities in the design, synthesis, and analysis of a wide variety of engineering systems. The program focuses on developing design methodologies that involve high degree of research orientation supplemented with practical insights. Besides core courses, a variety of electives are also offered to suit the interest of each student so that they can specialize in a particular area of Engineering Design. The master's program is committed to produce design engineers with excellent creative capabilities and caliber to solve real-life industrial problems using emerging tools such as AI & ML.

Vision of the Institute

To be a global leader in the delivery of engineering education, transforming individuals to become creative, innovative, and socially responsible contributors in their professions.

Mission of the Institute

- To provide best-in-class infrastructure and resources to achieve excellence in technical education
- To promote knowledge development in thematic research areas that have a positive impact on society, both nationally and globally
- To design and maintain the highest quality education through active engagement with all stakeholders – students, faculty, industry, alumni and reputed academic institutions
- To contribute to the quality enhancement of the local and global education ecosystem
- To promote a culture of collaboration that allows creativity, innovation, and entrepreneurship to flourish, and
- To practice and promote high standards of professional ethics, transparency, and accountability.

Vision of the Department

To transform our students into outstanding mechanical engineers with strong domain knowledge and skills, society-centric research intent, and exemplary ethical values, making them the most desired professionals by research institutions, industry and society.

Mission of the Department

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

Program Educational Objectives (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.

Mission Statement - PEO Mapping

Mapping	M1	M2	M3	M4
PEO1	3	3	2	3
PEO2	2	3	3	3
PEO3	3	2	3	2

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 independently carry out research/investigation and development work to solve practical problems

PO3: An ability to write and present a substantial technical report/document.

PO4: An ability to design, analyze and synthesize multi-physical engineering systems using modern tools and techniques.

PO5: An ability to conduct theoretical and experimental investigations on Industrial and societal problems to provide sustainable solutions.

CURRICULUM

Bridge Course: A comprehensive bridge course has been designed to equip students with a solid foundation in several key mathematical areas and programming proficiency crucial for their academic journey and future endeavors in engineering design. This intensive course aims to bridge the gap between prior knowledge and the rigorous demands of the program, ensuring all students possess a solid understanding of fundamental concepts in mathematics and programming languages.

The mathematics segment of the bridge course encompasses a diverse array of topics essential for the comprehension and analysis of advanced engineering principles. Students will be familiarized with Calculus, Linear Algebra, Complex variable, Transforms, Statistics, ODE and PDE. In parallel with mathematical concepts, students will be introduced to a versatile programming language, such as Python/MATLAB, to facilitate computational analysis and problem-solving in engineering contexts. Through hands-on exercises and projects, students will gain proficiency in Basic Syntax and Data Structures, Numerical Computing, Plotting and Visualization, Algorithm Implementation and Integration with engineering applications. (60 Hours)

Semester 1				
Course Code	**Type**	**Course**	**L T P**	**Cr**
24ED601	FC	Selection of Materials and Product Design	3 0 0	3
24ED602	FC	Optimization Techniques in Engineering	2 0 3	4
24ED603	FC	Machine Learning for Engineering Design	2 0 3	4
24ED604	SC	Advanced Solid Mechanics	3 0 0	3
24ED605	SC	Theory of Vibration	3 0 0	3
24ED606	SC	Introduction to Systems Engineering	2 0 3	2
22AVP103	HU	Mastery Over Mind	1 0 2	2
23HU601	HU	Career Competency I*		P/F
*** Non-credit Course**		**Hrs - 25**	**Credits**	**21**

Semester 2				
Course Code	**Type**	**Course**	**L T P**	**Cr**
24ED611	SC	Multi Body Dynamics	3 0 0	3
24ED612	SC	Finite Element Techniques	2 0 3	3
24ED613	SC	Computational Fluid Dynamics	2 0 3	3
	E*	Elective I	3 0 0	3
	E*	Elective II	3 0 0	3
	E*	Elective III	3 0 0	3
24ED681	SC	Engineering Design Lab	0 0 3	1
23HU611	HU	Career Competency II	0 0 3	1
24RM602		Research Methodology		P/F
		Hrs – 25	**Credits**	**20**

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

Semester 3				
Course Code	**Type**	**Course**	**L T P**	**Cr**
24ED798		Dissertation Phase I		10
			Credits	**10**

Semester 4				
Course Code	**Type**	**Course**	**L T P**	**Cr**
24ED799		Dissertation Phase II		16
			Credits	**16**

Total credits: 67

L- Lecture; T-Tutorial; P-Practical; FC- Foundation Core; SC- Subject Core; HU-Humanities; ADM-Amrita Darshanam; E-Electives; P- Dissertation; P/F- Pass/Fail

List of courses

Foundation Core

Course Code	Type	Course	L	T	P	Cr
24ED601	FC	Selection of Materials and Product Design	3	0	0	3
24ED602	FC	Optimization Techniques in Engineering	2	0	3	4
24ED603	FC	Machine Learning for Engineering Design	2	0	3	4

Subject Core

Course Code	Type	Course	L	T	P	Cr
24ED604	SC	Advanced Solid Mechanics	3	0	0	3
24ED605	SC	Theory of Vibrations	3	0	0	3
24ED606	SC	Introduction to Systems Engineering	2	0	0	2
24ED611	SC	Multi Body Dynamics	3	0	0	3
24ED612	SC	Finite Element Techniques	2	0	3	4
24ED613	SC	Computational Fluid Dynamics	2	0	3	4
24ED681	SC	Engineering Design Lab	0	0	3	1

Electives

Course Code	Type	Course	L	T	P	Cr
24ED631	E	Modelling, Simulation and Analysis of Engineering Systems	3	0	0	3
24ED632	E	Fundamentals of Analytical Dynamics	3	0	0	3
24ED633	E	Vibrations and control	3	0	0	3
24ED634	E	Advanced Finite Element Analysis	3	0	0	3
24ED635	E	Advanced Robotics	3	0	0	3
24ED636	E	Introduction to Nonlinear Dynamics and Chaos	3	0	0	3
24ED637	E	Theory of Plates and Shells	3	0	0	3
24ED638	E	Mechanics of Composite Materials	3	0	0	3
24ED639	E	Failure Analysis and Design	3	0	0	3
24ED640	E	Tribology	3	0	0	3
24ED641	E	Design for Manufacturing and Assembly	3	0	0	3
24ED642	E	Design Thinking	2	0	3	3
24ED643	E	Design for additive manufacturing	3	0	0	3
24ED644	E	Engineering Design-Product Architect	3	0	0	3
24ED645	E	Multi Objective Optimization	3	0	0	3
24ED646	E	Machine Condition Monitoring	3	0	0	3
24ED647	E	Reliability Engineering	3	0	0	3
24ED648	E	Mechatronics System Design	3	0	0	3
24ED649	E	Introduction to Digital Twin	3	0	0	3
24ED650	E	Noise Vibration and Harshness	3	0	0	3
24ED651	E	Robust Design	3	0	0	3
24ED652	E	Fracture and Fatigue	3	0	0	3
24ED653	E	Geometric Dimensioning and Tolerancing	3	0	0	3

Evaluation Pattern

Course Type	Int: Ext	Evaluation Scheme						Total (100)	
Theory, Lab integrated and Pass/Fail (P/F) Courses									
L T P	60: 40	CA1	CA2	MT	CA3	CA4	ES	Internal (60)	External (40)
		Q1 /AI	Q2/ A2	Exam	Q3/ A3	Q4/ A4	Exam/Project*	CA1+CA2+ CA3+CA4	ES
X 0 0		7.5	7.5	30	7.5	7.5	40	60	40
X Y 0									
X 0 Z									
P/F									
Lab Based Courses									
0 0 Z	60: 40	6 weeks Task or Exp. (CA1)		MT	6 weeks Task or Exp. (CA2)		ES	Total (100)	
		No. of Task based on the course			No. of Task based on the course		Exam/Project*	Internal (CA1+MT+CA2)	External (ES)
1 0 Z		20		20	20		40	60	40
Dissertation / Internship									
Dissertation / Internship	60:40	CA (60)					ES (40)	Total (100)	
		Dissertation Phase 1 & Phase 2							
		Based on Review by panel of experts					External Review	CA+ES	
		Internship							
		External report (Industry /Research Organization)					Presentation + Internship report	CA+ES	

Nomenclature

L	: Lecture	T	: Tutorial
P	: Practical	Int	: Internal
Ext	: External	CA	: Continuous Assessment
MT	: Mid-Term	ES	: End Semester Examination
Exp.	: Experimental work	X	: No. of Lecture hours per week
Y	: No. of Tutorial hours per week (1)	Z	: No. of practical hours per week
Q	: Quiz	A	: Assignment
DIS	: Dissertation		

*: Project component (in-lieu of end semester examination) only for the selected courses as decided by the department level committee

SEMESTER 1

24ED601 SELECTION OF MATERIALS AND PRODUCT DESIGN 3-0-0-3

Course Objectives

1. Explore material selection's pivotal role in mechanical design processes, providing advanced insights.
2. Equip engineering students with skills to make material decisions for design projects.
3. Examine material selection methods and their impact on product performance and failure prevention.

Course Outcomes

CO	CO Description
CO1	Understand design-oriented materials selection for different engineering applications
CO2	Familiarize materials selection methodology, processing and key properties for design.
CO3	Use various product development tools and methods to propose conceptual model
CO4	Understand industrial design requirements and provide sustainable solutions

CO-PO Mapping

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

Skills Acquired

Select suitable material for specific application, develop product design, and provide sustainable solution.

Mathematical Preliminaries: Nil

Unit 1 10 Hours

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

Unit 2 10 Hours

MATERIAL SELECTION STRATEGIES: Utilizing the Ashby method, material property charts, and indices for materials selection. Structural Considerations and Constraints: Addressing single and multiple constraints, conflicting objectives, and shape factors in materials selection. Exploration of Material-Shape Combinations: Investigating hybrid materials, composites, sandwich structures, cellular structures, and segmented structures.

Unit 3 10 Hours

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

Unit 4 15 Hours

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

Textbooks / References

1. M.F. Ashby, "*Materials Selection in Mechanical Design*", 5th Ed. Butterworth-Heinemann, 2016.
2. Ashby, M.F., Shercliff, H. and Cebon, D., "*Materials: engineering, science, processing and design*", Butterworth-Heinemann, 2018.
3. D.R. Askeland and P.P. Phule, "*The Science and Engineering of Materials*", Thomson Brooks/Cole Publication, 2011.
4. P. L. Mangonon, "*The Principles of Materials Selection and Design*", Prentice Hall International, Inc., 1999.
5. J.A.Charles, F.A.A Crane, J.A.G, Furness, "*Selection and use of Engineering Materials*", Butterworth Heinemann, 1997.
6. Ulrich, K. T., & Eppinger, S. D, "*Product Design and Development*", McGraw-Hill,7th Edition, 2020
7. Pruitt, J., & Adlin, T, "*The Persona Lifecycle: Keeping People in Mind throughout Product Design*". (E. Inc., Ed.). Morgan Kaufmann, 2010.
8. Shigley and Mische, "*Mechanical Engineering Design*", McGraw Hill, Inc., New Delhi, 8th edition, 2020.

24ED602 **OPTIMIZATION TECHNIQUES IN ENGINEERING** **2-0-3-4**

Course Objectives

The Course "Optimization Techniques in Engineering" aims to achieve the following objectives:

1. Understand the theory of optimization and the conditions for optimality in both unconstrained and constrained optimization problems
2. Gain familiarity with the working principles of optimization algorithms used to solve linear and non-linear problems
3. Study modern optimization methods such as Genetic Algorithms, Simulated Annealing, Particle Swarm Optimization, and Neural Network-based optimization
4. Develop practical skills by implementing optimization algorithms in software environments for solving linear and non-linear optimization problems

Course Outcomes

CO	CO Description
CO1	Formulate the Engineering Problems as an optimization problem
CO2	Apply necessary and sufficient conditions for a given optimization problem for optimality
CO3	Select appropriate solution methods and strategies for solving unconstrained and constrained optimization problem
CO4	Apply modern heuristic methods for solving complex optimization problems to obtain optimal / near-optimal solution
CO5	Interpret and analyze the solution obtained by optimization algorithms and improve their convergence and solution quality
CO6	Solve Engineering optimization problems using software tools.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	1	3	3
CO2	3	3	1	3	3
CO3	3	3	1	3	3
CO4	3	3	1	3	3
CO5	3	3	1	3	3
CO6	3	3	1	3	3

Skills Acquired

Mathematical formulation of physical problem as an optimization model; solving optimization problems using traditional & modern methods; Proficiency in implementing optimization algorithms using software tools; Solving real-world engineering optimization problems

Mathematical Preliminaries **8 Hours**

Review of - Calculus; Linear Algebra; Numerical methods; Statistics

Unit 1 **16 Hours**

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.

Lab Practice

- Introduction to software tool (Matlab / Python)
- Review essential mathematical concepts relevant to optimization, including calculus, linear algebra, and statistics and hands on practice using software tool
- Checking the optimality of unconstraint and constraint optimization problems
- Solving Linear / Mixed Integer programming problems

Unit 2 **16 Hours**

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.

Lab Practice

- Solving Quadratic, Non-Linear Unconstrained, and Constrained optimization problems and implement direct and gradient based approaches
- Study the convergence and divergence of algorithms and optimize the algorithm parameters

Unit 3 **16 Hours**

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 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, Fourth edition, 2019.
2. Deb, Kalyanmoy, "*Optimization for engineering design: Algorithms and examples*", PHI Learning Pvt. Ltd., Second edition, 2012.
3. Arora, J.S., "*Introduction to Optimum Design*", Academic Press, 4^{th} Edition, 2017.

24ED603 **MACHINE LEARNING FOR ENGINEERING DESIGN** **2-0-3-4**

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
CO1	Understand machine learning concepts for engineering design
CO2	Apply ML methods to model and optimize mechanical systems
CO3	Evaluate and validate ML models for better prediction accuracy
CO4	Apply ML for solving real time projects in Engineering design

CO-PO Mapping

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

Skills Acquired

Formulate 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.

Unit 1 **12 Hours**

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.

Unit 2 **16 Hours**

Machine Learning, Types – Linear Regression in one variable, Gradient descent, Regression in multiple variables – Linear models for classification, Discriminant functions, Logistic regression – Regularization techniques.
Classification - k-Nearest Neighbourhood (KNN), Decision Tree, Support Vector Machine, Naïve Bayes – Neural networks model representation, Feed-forward network functions, Network training, Back-propagation algorithm.

Unit 3 **17 Hours**

Deep learning - Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM). Generative Adversarial Network (GANs). Clustering - K-Means clustering, Hierarchical clustering. Reinforcement Learning. Model Evaluation and Validation - Cross-validation techniques, Evaluation metrics for regression and classification tasks, Bias-variance tradeoff, Feature Engineering and Model Optimization

Lab Practice **36 Hours**

1. Pattern recognition based on-line vibration monitoring system for machinery fault diagnosis using support vector machine.
2. Decision tree assisted selection of materials for electric vehicle chassis.
3. Predicting the optimal input parameters for the desired print quality using artificial neural network.
4. Exploration of K-NN algorithm to predict fatigue strength of steel from composition and processing parameters.
5. Prediction of remaining useful life of machine component using support vector regression and LSTM
6. Generation of 3D CAD model for mechanical parts using generative adversarial networks (GAN)
7. A deep learning approach for detection of obstacles for autonomous driving systems using CNN.
8. A multi-sensor information fusion for fault diagnosis of mechanical system utilizing discrete wavelet features.
9. Physics informed machine learning based fault diagnosis of machine elements.
10. Prediction of weld quality using image-processing techniques.

Textbook / Reference Books

1. Tom M. Mitchell, "*Machine Learning*", McGraw Hill, 1997.
2. Ethem Alpaydin, "*Introduction to Machine Learning*", MIT Press, 2015.
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, 2017.
5. Ian Goodfellow, Yoshua Bengio and Aeron Courville, "*Deep Learning*", MIT Press, First Edition, 2016.
6. Guttag, John, "*Introduction to Computation and Programming Using Python: With Application to Understanding Data*", Second Edition. MIT Press, 2016.

24ED604 **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 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

CO	CO Description
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 Inculcate the knowledge to formulate & solve continuum-based problems in Solid Mechanics
CO3	Formulate and solve continuum-based problems in the area of Solid Mechanics for different loading conditions
CO4	Analyse stresses, strains, and deflections using the Energy method
CO5	Analyse 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	1	3	
CO2	3	3		3	
CO3	3	3		3	2
CO4	3	3		3	2
CO5	3	3		3	2

Skills Acquired

Develop analytical models based on continuum theory to formulate and solve linear elastic problems in solid mechanics using material constitutive laws, compatibility conditions, and governing equations, and to analyse stresses, strains, and deflections in continua under varying loading conditions.

Mathematical Preliminaries **3 Hours**

Vector and tensor calculus

Unit 1 **15 Hours**

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.

Unit 2 **15 Hours**

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 behaviour of anisotropic materials like fiber reinforced composites. Beam theory & Shell theory, Failure Criteria, Introduction to Plasticity.

Special Problems/Case Studies **15 Hours**

- 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.

Textbooks / References

1. Sadd, Martin H., "*Elasticity: Theory, applications and Numeric*", Academic Press, Fourth edition, 2020.
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, 2017.
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.

24ED605 **THEORY OF VIBRATIONS** **3-0-0-3**

Course Objectives

1. Familiarize students with the mathematical modeling and analysis of vibration problems in engineering.
2. Ensure that the students gain theoretical and practical skills to address vibration problems in engineering systems.

Course Outcomes

CO	CO Description
CO1	Formulate, solve and analyze equations of motions of free and forced single, two and multi degrees of freedom vibration systems.
CO2	Formulate and solve matrix eigenvalue problem to find modes and study its properties in two and multi-degree of freedom systems
CO3	Design of passive vibration control strategies using undamped and damped vibration absorbers
CO4	Analyze the free vibration characteristics of continuous systems
CO5	Apply approximate methods to find the vibration characteristics of continuous systems

CO-PO Mapping

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

Skills Acquired

- Modeling and analysis linear dynamical systems.
- Improved analytical and computational skills to deal with complex systems
- Provide strategies to control vibrations in different applications.
- Gain background to perform research in advanced areas of dynamics and vibrations.

Mathematical Preliminaries **5 Hours**

Basics of linear algebra – eigenvalue problems. Ordinary and partial differential equations. Basics of Laplace and Fourier transforms.

Unit 1 **12 Hours**

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.

Unit 2 **12 Hours**

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.

Unit 3 **8 Hours**

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.

Unit 4 **8 Hours**

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.

Textbooks / 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*", 5 th 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, 2^{nd} edition 2002.
5. J.P Den Hartog, "*Mechanical vibrations*", Dover publications, 1985.
6. D.J Inman, "*Engineering Vibration*", Pearson, 5^{th} edition, 2023.

24ED606 **INTRODUCTION TO SYSTEMS ENGINEERING** **2-0-3-2**

Course Objectives

1. Introduce systems science and systems engineering theory that pertain to creation of multi-disciplinary solutions to complex systems
2. Build an appreciation and provide insights into key systems engineering practices
3. Provide an overview of various development lifecycle activities pertaining to systems engineering of complex systems

Course Outcomes

CO	CO Description
CO1	Apply different holistic approaches to the study of complex systems.
CO2	Understand properties of complex system like hierarchy, auto-organization and emergence.
CO3	Model and analyse complex systems using dynamical system approach
CO4	Analyse complex systems using causal loop and stock flow diagrams
CO5	To apply model-based systems engineering to analyse complex systems

CO-PO Mapping

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

Skills Acquired

Creation of Causal Loops and Stock flow diagrams for System dynamics.
Acquiring skill in creation of MBSE models for advanced engineering Systems

Mathematical Preliminaries: Basics of Probability and Statistics **4 Hours**

Unit 1 **10 Hours**

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 mind. Systems definition of complexity, examples, structural and functional hierarchies, formation of complex systems, auto-organization, emergent phenomena, systems and network, multiple and spatial time scales, evolution of systems, adaptive systems and systems of systems. Nonlinearity and chaos in complex systems. System dynamics- system modeling, types of models.

Unit 2 **10 Hours**

System life cycle stages – requirement definition – architecture definition – design definition – system analysis – interface management - system integration – system verification – system transition – system validation – system operation – system maintenance – system disposal – project planning – project management & control – decision management – risk management – configuration management – quality assurance – acquisition/ supply – tailoring process & application.,

Unit 3 **15 Hours**

Introduction to system modeling & simulation – Definition and scope of MBSE
Evolution of MBSE-Benefits and challenges of MBSE-Introduction to SysML (Systems Modeling Language) Overview of other modeling languages -Understanding modeling notations and diagrams
Capturing system requirements using models-Requirements analysis and validation.
Traceability in MBSE-Architectural modeling concepts -Developing system architectures using SysML-System decomposition and allocation-Modeling system behavior with activity diagrams State machines and their application in MBSE-Simulation and analysis of system behavior Model-based verification of system properties-Real-world examples of MBSE applications
Case studies from different industries (aerospace, automotive, etc.)

Textbooks / References

1. Kossiakoff, Alexander and William N. Sweet; "*Systems Engineering: Principles and Practice*" John Wiley & Sons, 2nd edition, 2011
2. "*INCOSE Systems Engineering Handbook*", Wiley, 5th edition, 2023
3. System Engineering Book of Knowledge, www.sebokwiki.org
4. National Aeronautics and Space Administration, NASA Systems Engineering Handbook, (Rev1, December 2007)
5. Faulconbridge, R.I. and Ryan, M. J., "*Systems Engineering Practice*", Canberra: Argos Press, Revised Edition 2018.
6. ISO/IEC/IEEE 15288:2023 - *Systems and software engineering — System life cycle processes*
7. Blanchard, Benjamin S., and Wolter J. Fabrycky. "*Systems Engineering and Analysis*". Pearson, 5th Edition, 2023
8. Olivier L. de Weck, Daniel Roos, and Christopher L. Magee, "*Engineering Systems*", MIT Press, 2016

SEMESTER 2

24ED611 **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
CO1	Perform analytical formulation and solution of planar mechanisms
CO2	Formulate and solve multi-body dynamic problems using different techniques.
CO3	Perform analysis of spatial mechanisms using multi-body dynamics formulation.
CO4	Write computer programs to solve multi-dynamics problems.

CO-PO Mapping

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

Skills Acquired

The students can formulate equations of motion of planar and spatial dynamical systems and solve numerically the equations for the resulting motion through computer programs.

Mathematical Preliminaries

Linear Algebra, Variational Calculus, ODEs, and Numerical integration and matrix algebra.

Introduction to Multibody Dynamics **8 Hours**

Fundamental concepts of motion analysis and degrees of freedom within multibody systems. Introduction to kinematic and dynamic analysis techniques, multibody behavior. Introduction to Constraints in Multibody Systems: Role of constraints, impact on the motion and behavior of interconnected rigid bodies.

Kinematics of Rigid Bodies **8 Hours**

Velocity and acceleration equations for rigid bodies, Constrained kinematics and the formulation of driving and joint constraints in multibody systems. Introduction to computational methods, kinematic analysis for modeling and simulating complex multibody systems.

Forms of Dynamic Equations **8 Hours**

D'Alembert's principle and Newton-Euler equations in formulating dynamic equations. Constrained dynamics, augmented formulation for solving dynamic problems. Embedding techniques and amalgamated formulation for representing dynamic equations in multibody systems.

Virtual Work and Lagrangian Dynamics **8 Hours**

Principles of constrained dynamics and virtual work, application in analyzing multibody systems. Techniques for eliminating constrained forces, Lagrangian multipliers in dynamic analysis. State Space Representation and techniques for implementing sparse matrices in computational methods.

Spatial Dynamics **8 Hours**

Introduction to Euler Angles and their application in analyzing three-dimensional motion of multibody systems. Deriving dynamic equations of motion for spatial systems and analyzing their implications. Analysis of linear and angular momentum and their significance in analyzing multibody systems.

Practical applications and case studies.

Textbooks / References

1. Ahmed. A. Shabana, "*Computational Dynamics*", Third Edition, John Wiley, 2010.
2. Ahmed. A. Shabana, "*Dynamics of Multibody Systems*", Fourth Edition, Cambridge University Publications, 2013.
3. Amirouche, "*Fundamentals of multibody dynamics: theory and applications*". Springer Science & Business Media,2013
4. Nikravesh P. E., "*Planar Multibody Dynamics-formulation, Programming and Applications*", CRC Press, 2007.
5. Nikravesh P. E., "*Computer Aided Analysis of Mechanical Systems*", Prentice Hall, 1988.

24ED612 **FINITE ELEMENT TECHNIQUES** **2-0-3-3**

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, Galerkin, 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 analyse, 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	1	2	2
CO2	3	3	1	2	2
CO3	3	3	1	2	2
CO4	3	3	1	2	2
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.

Unit 1 **10 hours**

Mathematical Preliminaries: Vectors, Tensors, Differential Equations and Linear Algebra, Fundamentals of governing equations in Solid Mechanics and Heat Transfer. Basic finite element procedures: Direct Stiffness Method, Principle of Minimum Potential Energy.

Unit 2 **15 hours**

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.

Formulation in Solid Mechanics: Strong form, Weak form or Variational formulation, Weighted Residual Method - Galerkin formulation, Isoparametric formulation and elements.

Unit 3 **20 hours**

Formulation 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 Content **24 hours**

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)**

Textbooks / References

1. Thomas J. R. Hughes, "*The Finite Element Method – Linear Static and Dynamic Finite Element Analysis*", Dover Publications Inc, 2012.
2. Rao S. S., "*The Finite Element Method in Engineering*", Fourth Edition, Elsevier, 2017.
3. Daryl L. Logan, "*A First Course in the Finite Element Method – Enhanced Edition, SI Version*", Fourth Edition, Cengage Learning, 2022.
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, 2012.
6. Zienkiewicz O. C., "*The Finite Element Method for Solid and Structural Mechanics*", Sixth Edition, Butterworth-Heinemann, 2013.
7. Jacob Fish and Ted Belytschko, "*A First Course in Finite Elements*", Wiley Inter Science, 2007. DS Simulia, "*Abaqus Documentation*", Abaqus version 2024.

24ED613 **COMPUTATIONAL FLUID DYNAMICS** **2-0-3-3**

Course Objectives

1. To familiarize on the basic governing equations and the basic properties of CFD.
2. To utilize different discretization techniques and solving methods for improving accuracy.
3. To solve real time physical problems using simulation software.

Course Outcomes

CO	CO Description
CO1	Understand the classification of PDEs, governing equations and basic properties of computational methods.
CO2	Apply finite volume method to solve steady and unsteady diffusion, advection-diffusion problems
CO3	Apply the various discretization methods, solution procedures and turbulence modeling to solve flow and heat transfer problems.
CO4	Apply the knowledge to interpret, solve and analyze engineering flow problems.

CO-PO Mapping

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

Skills Acquired

Numerical Simulation: Discretization methods, numerical algorithms, stability, and convergence analysis.
Practical Application: Using CFD software, solving real-world fluid dynamics problems, and modeling complex systems.
Advanced Techniques: Turbulence and combustion modeling, advanced schemes, and integrating machine learning with CFD.

Mathematical Preliminaries **3 Hours**

Numerical solution of system of Linear Equation

Unit 1 **10 Hours**

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

Unit 2 **12 Hours**

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.

Unit 3 **8 Hours**

Discretization of Navier Stokes Equations, primitive variable approach, SIMPLE Algorithm, SIMPLER Algorithm, Introduction to Turbulence Modeling, spray and combustion modeling,

Lab **45 Hours**

Applications to practical problems using OpenFoam / PyCFD and other commercial softwares.

Lab Exercises

1. Boundary layer flows (Flow through pipe and over a flat plate)
2. Flow around a cylinder (unsteady).
3. Compressible flow through a CD nozzle.
4. Lid driven cavity flow using OpenFoam.
5. A sector modelling and analysis of internal combustion engines using Ansys Forte.
6. Battery thermal modeling for Li-ion battery packs.
7. Convolution Neural Network based solution for 2D steady state Navier Stokes equation.

Textbooks / References

1. Versteeg, H.K., and Malalasekara, W, "*An Introduction to Computational Fluid Dynamics*", An: The Finite Volume Method, 2nd Edition, Pearson, 2007
2. Moukalled, F., Mangani, L., and Darwish, M. "*The finite volume method in computational fluid dynamics. An Advanced Introduction with OpenFOAM and Matlab*", Springer, 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, 3rd Edition, 2012.

24ED681 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 fatigue, creep and wear resistance of the material.
3. Familiarize advanced vibration testing for design of dynamic systems

Course Outcomes

CO	CO Description
CO1	Conduct various testing on materials to understand its mechanical behavior and determine its properties
CO2	Investigate the change in fatigue, creep and wear resistance of the material based on various factors
CO3	Perform various vibration testing and analysis for design of mechanical systems

CO-PO Mapping

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

Skills Acquired

Determine the mechanical properties of the material by conducting various material testing; Study the effect of materials resistance under various factors; Design dynamic mechanical systems by performing vibration testing.

Materials Testing and Measurement 27 Hours

1. Estimate the tensile strength of polymer and composite materials using Tensile Testing machine.
2. Determine the mechanical properties of 3D printed polylactic acid and investigate the effects of temperature, layer thickness, infill direction and speed on mechanical properties.
3. Estimate the flexural strength of polymer composite materials using three-point bending test.
4. Predict the buckling strength of steel with various cross sections using numerical analysis and validate the results with experimental studies.
5. Study the effect of surface roughness and corrosion factors in high fatigue strength metals using fatigue testing machine.
6. Experimental investigation of creep strength in welded joints.
7. Study the effect of heat treatment process on hardness and wear behavior of metallic materials.

Vibration Testing and Measurement 18 Hours

1. Estimate the damping properties of lightweight materials for automobile engine mountings using Impact hammer test.
2. Study of damping characteristics of sandwiched structure using vibration exciter.
3. Conduct experimental modal analysis to determine the dynamic behavior of a structure and validate the results with numerical analysis.
4. Vibration path identification and optimization to enhance automotive NVH performance through transfer path analysis.
5. Analyze vibration signature of a rotating machine and assess the health condition of machine.

24RM602 **RESEARCH METHODOLOGY** **P/F**

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
CO1	Understand research problem formulation
CO2	Analyse research related information
CO3	Follow research ethics
CO4	Understand that today’s world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
CO5	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
CO6	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	PO4	PO5	PO6
CO1	1	1	2			
CO2	1	1	3			
CO3	1	1	2			
CO4	1		3			
CO5	1	1	2			
CO6						

Skills Acquired:

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

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, 3rdEdition, "*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

ELECTIVES

24ED631 MODELLING, 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
CO1	Perform mathematical modeling of physical systems using fundamental principles.
CO2	Analyze the mathematical models using time and frequency domain methods
CO3	Perform state space analysis of linear time invariant systems
CO4	Perform optimal control design for engineering systems

CO-PO Mapping

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

Skills Acquired

- Learn to model and analyze engineering systems using math tools.
- Understand system behavior for designing stable control systems.
- Gain skills in simulation and problem-solving for real-world challenges.

Mathematical Preliminaries **5 Hours**

Linear algebra, differential equations, Laplace transforms, Control theory system dynamics, and state space analysis.

Unit 1 **12 Hours**

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.

Unit 2 **16 Hours**

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.

Unit 3 **10 Hours**

Introduction to Nonlinear systems, System identification and advanced topics
Characteristics of Nonlinear Systems, Common Nonlinearities, Analysis Techniques, Bifurcation and Chaos, System Identification – Basic concepts, methods, model structure selection, parameter estimation, validation. Nonlinear control and strategies.

Textbooks / 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*", JohnWiley, 2008.

24ED632 **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
CO1	Analyse mechanical systems using Newtonian framework
CO2	Use virtual work and variational calculus to analyse systems
CO3	Arrive at governing equations using Lagrangian and Hamiltonian formalisms
CO4	Apply coordinate transformations to study practical problems
CO5	Use Legendre and canonical transformations to analyse system

CO-PO Mapping

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

Unit 1 **12 Hours**

Newtonian Mechanics: Foundational aspects of classical mechanics, Newton's laws, impulse, momentum, moment of a force, angular momentum, work, and energy. Dynamics of systems of particles and two-body central force problem**.**

Unit 2 **13 Hours**

Analytical Mechanics: Generalized coordinates, constraints, variational calculus, principle of virtual work, D'Alembert's principle, Hamilton's principle, and Lagrange's equations of motion, Principles governing classical mechanics and their mathematical formulations.

Unit 3 **20 Hours**

Motion Relative to Rotating Reference Frames: Transformation of coordinates and the dynamics of systems relative to rotating and moving frames. Complexities of motion in non-inertial reference frames.
Rigid Body Dynamics: Dynamics of rigid bodies, kinematics, linear and angular momentum, translation theorem for angular momentum, kinetic energy, principal axes, equations of motion, and Euler's angles. Motion of rigid bodies.
Hamiltonian Mechanics: Principle of least action, Legendre transformation, Hamilton's equations, Poisson's brackets, canonical transformations, and Hamilton-Jacobi equations. Classical mechanics and its connections to other areas of physics.

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.

24ED633 **VIBRATION AND CONTROL** **3-0-0-3**

Course Objectives

1. Make the students familiar with the necessity of vibration control in engineering applications.
2. Learn passive and active control strategies to control vibrations in different scenarios.

Course Outcomes

CO	CO Description
CO1	Understand the different sources of vibrations and the effect of them on the dynamics of the system.
CO2	Understand the importance of different types of damping in vibration control applications.
CO3	Apply different passive control strategies in controlling vibrations.
CO4	Apply active control strategies in controlling vibrations.

CO-PO Mapping

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

Skills Acquired

- Analyse single and two-degree-of-freedom systems, solve eigenvalue problems, and design vibration dampers, including nonlinear systems.
- Balance rigid and flexible rotors, apply structural damping models, and select materials for enhanced damping.
- Implement active control using classical systems, piezoelectric sensors, and design energy harvesting systems.

Mathematical Preliminaries

Llinear algebra – eigenvalue problems. Ordinary and partial differential equations. Basics of Laplace and Fourier transforms

Unit 1 **15 Hours**

Introduction to Vibrations: Review of single degree and two degree of freedom systems- Free and forced vibrations – Eigenvalue problems and its solution - equivalent viscous damping-vibration isolators – Transmissibility- effect of damping on linear vibration isolators. Introduction to nonlinear vibration isolators. Undamped and damped vibration absorbers – Design of tuned vibration dampers for different applications. Introduction to nonlinear vibration absorbers.

Vibration reduction at the source: Introduction, Balancing, Balancing of Rigid Rotors, Balancing Machines, Field Balancing, Balancing of Flexible Rotors, Vortex Induced Vibration, Detuning and Decoupling.

Unit 2 **15 Hours**

Vibration control by structural design: Damping Models and Measures, Origin of Structural Damping, Damping-Stress Relationship, Selection Criteria for Linear Hysteretic Materials, Combined Fatigue-Strength Damping Criteria, Design for Enhanced Material Damping.

Viscoelastic material for vibration damping: Standard Linear Solid – constitutive models, Stress-strain relationship, Complex Modulus, Frequency temperature dependence of complex modulus, Representation of Complex Stiffness, Free Layer Damping, Constrained Layer Damping, Viscoelastic Joints, Bonded Rubber Springs.

Unit 3 **15 Hours**

Active Vibration Control: Introduction to Closed Loop Control, Classical Control System, Piezoelectric Sensors and Actuators, Vibration Control of Flexible Beam, Energy Harvesting System.

Textbooks / References

1. Mallik, Asok Kumar, and Shyamal Chatterjee. "*Principles of passive and active vibration control*." East West Press , 2014
2. Meirovitch, Leonard. "*Dynamics and control of structures*". John Wiley & Sons, 1991.
3. Preumont, André. "*Vibration control of active structures: an introduction*". Springer, 4th Edition, 2018.
4. Inman, Daniel J. "*Vibration with control*", 2nd Edition, John Wiley & Sons, 2017.

24ED634 **ADVANCED FINITE ELEMENT ANALYSIS** **3-0-0-3**

Course Objectives

1. Inculcate the knowledge to develop finite element techniques to solve 1D and Multi-D non-linear and dynamic responses of structures
2. Inculcate the knowledge to formulate Strong, Weak, Galerkins, and Matrix forms to analyze and predict the response of advanced engineering phenomena and structures
3. Inculcate the knowledge to use higher order elements, mesh refinement techniques, and mixed formulations to solve advanced finite element problems
4. Utilize commercial finite element packages to model, solve, and analyze complex and non-linear engineering problems

Course Outcomes

CO	CO Description
CO1	Apply finite element methods to solve advanced engineering problems in multiphysics using different formulations and error estimates
CO2	Develop proficiency in advanced finite element methods, including higher-order elements and adaptive mesh refinement
CO3	Formulate and Analyze dynamic response of structures using implicit and explicit schemes
CO4	Evaluate nonlinear phenomena such as geometric, material, and boundary for accurate estimation of real-world engineering phenomena

CO-PO Mapping

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

Skills Acquired

Develop analytical and numerical models using the methodology of finite elements to solve and analyze nonlinear problems involving single and multi-physics, and to effectively utilize commercial finite element packages for solving real-world engineering problems.

Mathematical Preliminaries

Basics of FEM, calculus of variations, Linear Algebra.

Unit 1 **15 hours**

Advanced Finite Elements: Higher Order Elements: Introduction to quadratic and cubic elements for improved accuracy. Lagrangian and Eulerian Formulations, Adaptive Mesh Refinement based on error indicators to improve solution accuracy, Error Estimates: Discretization, approximation and truncation error estimates, error minimization techniques, Mixed and Hybrid Finite Element Methods for improved accuracy, Reduced Integration Techniques: locking phenomena: volumetric locking, shear locking.

Unit 2 **15 hours**

Dynamic Analysis: Structural Dynamics: Formulation of dynamic equations, eigenvalue problems: natural frequencies and mode shapes, Techniques to analyze transient and harmonic dynamic responses of structures, Implicit and Explicit Schemes to solve dynamic problems.

Unit 3 **15 hours**

Nonlinear Finite Element Analysis: Introduction to geometric, material, and boundary nonlinearities: methods to solve non-linear elastic and non-linear plastic problems, contact, and buckling problems, visco-elastic, and visco-plastic problems

Projects and case studies on real-world engineering problems.

Textbooks / References

1. Thomas J. R. Hughes, "*The Finite Element Method – Linear Static and Dynamic Finite Element Analysis*", Dover Publications Inc, 2012.
2. Ted Belytschko, Wing Kam Liu, Brian Moran, "*Nonlinear Finite Elements for Continua and Structures*", John Wiley & Sons, Ltd., 2014.
3. N.H. Kim, "*Introduction to Nonlinear Finite Element Analysis*", Springer publications, 2015.
4. Daryl L. Logan, "*A First Course in the Finite Element Method – Enhanced Edition, SI Version*", Fourth Edition, Cengage Learning, 2022.
5. Zienkiewicz O. C., "*The Finite Element Method for Solid and Structural Mechanics*", Sixth Edition, Butterworth-Heinemann, 2013.
6. René de Borst, Mike A. Crisfield, Joris J. C. Remmers, Clemens V. Verhoosel, "*Nonlinear Finite Element Analysis of Solids and Structures*, 2nd Edition" John Wiley & Sons, 2012.
7. M. A. Crisfield, "*Non-Linear Finite Element Analysis of Solids and Structures*, Volume 2, Advanced Topics", John Wiley & Sons, 2000.
8. DS Simulia, "*Abaqus Documentation*", Abaqus version 2024.

24ED635 **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
CO1	Select the suitable robot for the application and estimate the appropriate gripping force
CO2	Analyse the forward and inverse kinematics for serial manipulator
CO3	Analyse the forward and inverse kinematics for parallel manipulator
CO4	Analyse the forward and inverse dynamics for serial manipulator
CO5	Develop the suitable trajectory algorithm for the given application

CO-PO Mapping

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

Skills Acquired

The students can analyze gripping force, formulate equations of motion of serial and parallel robotic manipulator systems and select appropriate trajectory for the given joint angle/velocity profile.

Mathematical Preliminaries **5 Hours**

Linear Algebra, Variational Calculus, ODEs, and Numerical integration and matrix algebra.

Unit 1 **6 Hours**

Introduction- Robot anatomy, types of robots, specifications, work volume, Robot precision movements, end effector, gripper force analysis. Robot applications.

Unit 2 **18 Hours**

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, problems. Singularity analysis.

Unit 3 **16 Hours**

Robot dynamics: Lagrangian formulation, Newton-Euler formulation, Forward and inverse dynamics of serial manipulator, problems.

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*". 1st Edition, Springer Science & Business Media, 2006.
4. John Craig. "*Introduction to robotics: mechanics and control*", 4th Edition, Pearson Education India, 2022.

24ED636 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
CO1	Analyse nonlinear dynamical systems using qualitative (also called geometric) approach.
CO2	Analyse one-dimensional, two-dimensional and multi-dimensional nonlinear systems using analytical and numerical tools.
CO3	Analyse different bifurcations of nonlinear systems, their normal forms and applications.
CO4	Quantify and analyse chaotic systems and detail its applications, especially to mechanical systems.
CO5	Analyse engineering, ecological, electronic, biological and financial systems using tools of nonlinear dynamics.

CO-PO Mapping

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

Unit 1 15 Hours

Introduction and Motivation, Examples. 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, dynamical classification based on eigenvalues, planar nonlinear systems, 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.

Unit 2 15 Hours

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.

Unit 3 15 Hours

Analytical methods for nonlinear systems - Perturbation method, Secular terms, Lindsted - Poincare method, averaging method, method of multiple scales. Application to two degree of freedom systems. Synchronisation in self-excited systems, Forced and mutual synchronisation, Arnold tongue and bifurcations, applications to biological and flow induced vibration problems.

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.
8. J. Awrejcewicz, "*Asymptotic multiple scale method in time domain*", CRC Press, 2023.
9. A. Balanov, "*Synchronization from simple to complex*", Springer, 2008.

24ED637 THEORY OF PLATES AND SHELLS 3-0-0-3

Course Objectives

1. Familiarize the concept of plate and study the behavior 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 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

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

Mathematical Preliminaries: (Differential Equations – 5 hours)

Unit 1 15 Hours

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.

Unit 2 15 Hours

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.

Unit 3 15 Hours

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.

Textbooks / References

1. Timoshenko S. and Woinowsky Krieger S., "*Theory of Plates and Shells*", McGraw-Hill, 2017.
2. Bhavikatti, S.S., "*Theory of Plates and Shells*", New Age International Pvt Ltd, 2017.
3. Chandrashekhara K., "*Theory of Plates*", Universities Press, 2001.
4. Vardhan T. K. and Bhaskar K., "*Analysis of Plates: Theory and Problems*", John Wiley & Sons, 1999.

24ED638 **MECHANICS OF COMPOSITE MATERIALS** **3-0-0-3**

Course Objectives

1. Familiarize composite materials terminology, classification, and concepts.
2. Analyze and predict mechanical behavior of composites under various loads.
3. Apply advanced techniques to design and optimize composite structures.

Course Outcomes

CO	CO Description
CO1	Classify composite materials and their manufacturing processes.
CO2	Predict mechanical behavior using stress and strain analysis.
CO3	Apply lamination theory and perform finite element analysis for composite design.
CO4	Evaluate mechanical properties and failure criteria for structural integrity.
CO5	Design composite structures considering load transfer, fatigue, and environmental factors.

CO-PO Mapping

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

Skills Acquired

Methodology of fabrication of composite laminate, Analysis of laminated structures, Performance evaluation of laminated structures

Mathematical Preliminaries **5 Hours**

Basics of Linear Algebra, Advanced Mechanics of Materials and Tensorial Notations.

Unit 1 **10 Hours**

Overview of composite materials and their classifications, Historical development and evolution, Advantages and limitations. Terminologies - fiber volume fraction, aspect ratio, ply orientation, and stacking sequence. Various manufacturing techniques - hand lay-up, filament winding, resin transfer molding (RTM), pultrusion, and autoclave curing. Advantages and limitations. Overview of the steps: material selection, mold preparation, lay-up, curing, Mechanical Properties, Stress-strain behavior.

Unit 2 **15 Hours**

Post-Processing. Non-destructive testing (NDT), visual inspection, ultrasonic testing, and thermography. Analysis of elastic constants, Role of microstructure, fiber-matrix interactions and fiber orientation. Failure mechanisms- fiber breakage, matrix cracking, delamination, and fiber pull-out.

Classical lamination theory - mechanical behavior of laminated composites. Strength prediction -maximum stress criteria, maximum strain criteria, and Tsai-Hill failure criteria. Finite element analysis, Micro and Micromechanical modeling - Halpin-Tsai equations, Voigt-Reuss-Hill approximation, and Mori-Tanaka method.

Unit 3 **15 Hours**

Design principles, load transfer mechanisms, stress concentration factors, and laminate optimization techniques. Fatigue and durability considerations, fatigue life prediction, damage tolerance, and environmental effects. Influence of temperature, moisture, and chemical exposure on the mechanical properties and performance of composite materials. Case studies and real-world applications of composite materials in engineering design.

Textbooks / References

1. Kaw, A.K., *Mechanics of composite materials*, 2nd Edition, CRC press, 2005.
2. Robert M. Jones, "*Mechanics of Composite Materials*", Second Edition, Taylor and Francis, 1999.
3. Mallick P. K., "*Fiber Reinforced Composite Materials - Manufacturing and Design*", 3rd Edition Marcel Dekker, 2008.
4. Halpin J. C., "*Primer on Composite Materials Analysis*", Techomic, 2nd Edition, 1992.
5. Mallick P. K. and Newman S., "*Composite Materials Technology - Processes and Properties*", Hansen, 1991.
6. Agarwal B. D. and Broutmen L. J., "*Analysis and Performance of Fibre Composites*", John Wiley &Sons, 2017.

24ED639 **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	Describe and distinguish common engineering failure mechanisms
CO2	Identify the nature and cause of defects in a machine component
CO3	Predict the life of components subjected to fatigue and creep
CO4	Characterize and analyze failures in engineering components

CO-PO Mapping

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

Unit 1 **10 Hours**

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

Unit 2 **15 Hours**

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.

Unit 3 **20 Hours**

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.

Textbook / Reference Books

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*", 2nd Edition, Wiley, 2013
4. Ralph I. Stephens, Ali Fatemi, Robert R. Stephens, Henry O.Fuchs, "*Metal fatigue in Engineering*", 2nd Edition, Wiley, 2001.
5. Colangelo Vito J. and Heiser F., "*Analysis of Metallurgical Failures*", 2nd 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*", 2nd Edition, 2021, John Wiley & Sons.

24ED640 **TRIBOLOGY** **3-0-0-**3

Course Objectives

1. Inculcate the knowledge on theories of friction and lubrication to predict frictional behaviour.
2. Characterize the features of engineering surfaces and analyze its surface topography
3. Explore factors influencing the selection of bearing materials for different applications

Course Outcomes

CO	CO Description
CO1	Understand the concepts of tribology and its application
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

	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

Mathematical Preliminaries: Nil

Unit 1 **15 Hours**

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.

Unit 2 **15 Hours**

Ferrography - Oil Analysis Program - Basic equations of Flow, Navier-Stokes equation, Generalized Reynolds equation-Types of lubrication, lubrication regimes, Hydrodynamic lubrication-Boundary lubrication-Bearing materials-Hydrodynamic real (finite) bearings-Design considerations in journal and thrust bearings - Hydrodynamic instability-Design of Hydrodynamic bearing.

Unit 3 **15 Hours**

Design of hydrostatic air/gas bearings, Elasto-hydrodynamic bearings, Idealized slider and journal bearings, Oil flow and Thermal analysis of bearings-Bearing selection and design-Dynamically loaded. Surface engineering-Surface modification and surface coatings.

Textbooks / References

1. Majumdar B. C., "*Tribology of Bearings*", S. Chand & Company Ltd., 2008.
2. Bharat Bhushan, "*Introduction to Tribology*", 2nd Edition, 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.

24ED641 DESIGN FOR MANUFACTURING AND ASSEMBLY 3-0-0-3

Course Objectives

1. Familiarize the concept and application of Design for Manufacturing and Assembly (DFMA) and its impact on product cost, quality, and sustainability.
2. Apply advanced techniques to optimize tolerances and manufacturing processes for enhanced manufacturability.
3. Evaluate environmental impacts and implement sustainable practices in DFMA processes.
4. Analyze and improve upon existing products using DFMA guidelines and principles in alignment with industry standards.

Course Outcomes

CO	CO Description
CO1	Analyze design fundamentals, and material selection processes, and assess cost implications for various products.
CO2	Apply advanced design guidelines for a range of manufacturing processes including additive manufacturing, advanced machining, and metal extrusion.
CO3	Evaluate environmental impacts and implement sustainable practices in DFMA processes.
CO4	Demonstrate the ability to analyze and improve existing products using DFMA principles.

CO-PO Mapping

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

Skills Acquired

- DFMA Mastery: Skill in applying DFMA principles to streamline product design and manufacturing processes.
- Advanced Design Proficiency: Ability to utilize GD&T, value engineering, and material selection to create highly optimized designs.
- Advanced Manufacturing Expertise: Proficiency in employing casting, machining, metal forming, and additive manufacturing techniques to realize complex designs.
- Sustainability Integration: Competence in integrating advanced joining techniques and sustainability principles into design practices to develop environmentally conscious manufacturing solutions.

Unit 1 15 Hours

Classification of the manufacturing process, Basic manufacturing processes, 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.

Unit 2 16 Hours

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.

Unit 3 **14 Hours**

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.

Textbooks / References

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

24ED642 **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
CO1	Understand the diverse methods employed in design thinking and establish a workable design thinking framework to use in their practices
CO2	Examine critical theories of design, systems thinking, and design methodologies.
CO3	Create great designs, be a more effective engineer, and communicate with high emotional and intellectual impact.
CO4	Conceive, organize, lead and implement projects in interdisciplinary domain and address social concerns with innovative approaches

CO-PO Mapping

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

Skills Acquired

Problem solving ability, creativity, innovative practice, product development, team work,

Unit 1 **12 Hours**

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.

Unit 2 **12 Hours**

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.

Unit 3 **6 Hours**

Sustainable product design, Ergonomics, Semantics, Entrepreneurship/business ideas, Branding, Advertising. Product Data Specification, establishing target specifications, setting the final specifications.

Design projects for teams **45 Hours**

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*", 9th Edition, Harvard business press, 2009.
5. Ulrich & Eppinger, "*Product Design and Development*", 7th Edition, McGraw Hill, 2020.
6. Stuart Pugh, "*Total Design: Integrated Methods for Successful Product Engineering*", 1st Edition, 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.

24ED643 **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

CO	CO Description
CO1	Inculcate working principle of metal and polymer additive manufacturing technologies
CO2	Understand the computational tools for design, analysis and optimization of AM parts
CO3	Impart a basic understanding of the DfAM strategic design considerations and part consolidation
CO4	Ensure the students to design and use guidelines for polymer and metal AM techniques

CO-PO Mapping

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

Skills Acquired

Knowledge on various additive manufacturing processes, design guidelines for different AM processes.

Unit 1 **10 Hours**

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 process.

Unit 2 **20 Hours**

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.

Unit 3 **15 Hours**

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

24ED644 ENGINEERING DESIGN-PRODUCT ARCHITECT 3-0-0-3

Course Objectives

1. To develop competencies of master's students in Engineering to carry Product Architect jobs.
2. To impart strong technical skill and holistic vision of product design flow
3. To introduce design and product development tools and methods used in engineering design
4. To ensure quality and performance of engineering design processes and product development.

Course Outcomes

CO	CO Description
CO1	Identify, analyze and synthesize all the stakeholders‟ needs and customer requirements
CO2	Design the product / system architecture in collaboration with the others and allocate each function into different sub-system
CO3	Ensure a consistent set of requirements considering the global vision of reduced cost of product design
CO4	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
CO1	2	1			2
CO2	2	1	1	1	2
CO3	2	1			2
CO4	2	1			2

Unit 1 15 Hours

Introduction to Product Design and Development Process: Overview of the product design lifecycle, Stages of product development, Importance of iterative design and feedback loops, Identifying and engaging stakeholders, Techniques for gathering and analyzing stakeholder requirements, Formalizing user product requirements, Methods for identifying product functions. Functional decomposition and hierarchical modeling, Tools and techniques for functional modeling Introduction to QFD and its role in product design, House of Quality matrix, Market segmentation and targeting, aligning product features with market needs and customer preferences

Unit 2 15 Hours

Product Architecture and Design Considerations: Definition and importance of product architecture, Modularity and its benefits in product design, Platform-based design and product families

Methods for defining product architecture, Creating and using Design Structured Matrix (DSM) for product development, Function allocation within the architecture, Overview of manufacturing processes and flow, estimating assembly costs and optimizing design for manufacturing (DFM), Basics of design for assembly (DFA), Strategies for effective supplier management and collaboration

Product cost analysis techniques, Value analysis and value engineering, Balancing cost, quality, and functionality in design

Unit 3 15 Hours

Product Design Processes, Organization, and Performance: Structuring product design teams and roles, Project organization and management in product design, Collaboration and communication within design teams, Principles of lean thinking applied to product development, Techniques for reducing waste and increasing efficiency in design processes, Implementing continuous improvement in product design, Introduction to systems engineering principles and practices, Integrating systems engineering into product development, Managing complexity and interdependencies in product design, Key performance indicators (KPIs) for product design, Methods for evaluating and improving design process performance. Case studies and examples of successful product design projects.

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*", 7th Edition, McGraw-Hill, 2020.
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*", 3rd Edition, Springer, 2007.
5. Brown, T, "*Design Thinking*", Harvard Business Review, 2008.

24ED645 MULTI OBJECTIVE OPTIMIZATION 3-0-0-3

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 engineering

Course Outcomes

CO	CO Description
CO1	Formulate Engineering problem as a multi-objective optimization problem
CO2	Apply evolutionary optimization techniques to solve complex Engineering problems involving multiple objectives using classical optimization approaches
CO3	Apply the concepts of Pareto optimality and generate non-dominated solutions using evolutionary algorithms for solving multi-objective optimization problems
CO4	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

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

Skills Acquired

Mathematical formulation of physical problem as an optimization model; solving optimization problems using traditional & modern methods; Proficiency in implementing optimization algorithms using software tools; Solving real-world engineering optimization problems

Mathematical Preliminaries 2 Hours

Review of - Calculus; Linear Algebra; Numerical methods; Statistics

Unit 1 8 Hours

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.

Unit 2 10 Hours

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

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

Unit 3 10 Hours

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.

Tutorial / Lab Practice: (Unit 2 & Unit 3) **15 Hours**

- 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 / Reference Books

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.

24ED646 **MACHINE CONDITION MONITORING** **3-0-0-3**

Course Objectives

1. Familiarize the concept of condition-monitoring for effective utilization of machines
2. Impart knowledge of prognosis for estimation of remaining useful life.

Course Outcomes

CO	CO Description
CO1	Select the proper maintenance strategies and condition monitoring techniques for identification of machinery failure.
CO2	Acquire and Process sound and vibration signals in a dynamic mechanical system
CO3	Predict the faulty component in a machine by analyzing the acquired vibration signals
CO4	Estimate the remaining useful life of the faulty component.

CO-PO Mapping

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

Mathematical Preliminaries **5 Hours**

Probability & Statistics, Linear Algebra, differential equation, Time series analysis.

Unit 1 **25 Hours**

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.

Unit 2 **13 Hours**

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.

Unit 3 **7 Hours**

Precision Manufacturing Process Monitoring with Acoustic Emission, Tool Condition Monitoring. Fault-Trending and Prognostics: Trend Analysis, Advanced Prognostics, Data-Driven Models and Hybrid Models.

Textbook / Reference Books

1. Robert Bond Randall, "*Vibration-Based Condition Monitoring: Industrial, Aerospace and Automotive Applications*", 2nd Edition, John Wiley & Sons, 2021.
2. George Vachtsevanos, Frank L. Lewis, Michael Roemer, Andrew Hessand BiqingWu., "*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.

24ED647 **RELIABILITY ENGINEERING** **3-0-0-3**

Course Objectives

1. Highlight the importance of reliability
2. Provide overview of basic methods to evaluate product and system reliability

Course Outcomes

CO	CO Description
CO1	Determine the reliability of a product by applying the knowledge of probabilistic concept.
CO2	Identify and select the various failure models
CO3	Identify and select different reliability testing methods
CO4	Predict the reliability of a product using failure data.

CO-PO Mapping

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

Skills Acquired

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

Mathematical Preliminaries **5 Hours**

Linear Algebra-Calculus-probability and statistics.

Unit 1 **10 Hours**

Concept and Definition, Reliability mathematics, Failure distributions and hazard models, Exponential, Rayleigh, Weibull, Normal, and Lognormal distributions, Measures: MTTF (Mean Time To Failure), MTBF (Mean Time Between Failures).

Unit 2 **15 Hours**

Reliability Analysis of Systems: Series and parallel configurations, Reliability improvement techniques, Redundancy and k-out-of-n systems, Reliability assessment for complex configurations. Reliability Modeling: Reliability of three-state devices, Markov analysis for reliability assessment, Physical reliability models, Random stress and random strength considerations, Reliability-based design principles, First-order reliability methods, Reliability index and allocation strategies, Derating techniques.

Unit 3 **15 Hours**

Design for maintainability principles Availability assessment and improvement strategies, Maintenance planning and space provisioning considerations, Failure Data Analysis and Reliability Testing, Identifying failure distributions, Parameter estimation techniques, Reliability testing methodologies

Case Study: Application of intelligent control approaches in reliability engineering.

Textbooks / References

1. Charles Ebeling, "*An introduction to Reliability and Maintainability Engineering*", Tata McGraw Hill, 2017.
2. Lewis E. E., "*Introduction to Reliability Engineering*", 3rd Edition, John Wiley & Sons, 2022.
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*", McGraw Hill, 1997.

24ED648 MECHATRONICS SYSTEM DESIGN 3-0-0-3

Course Objectives

1. To make students understand mechatronic system components, including sensors, actuators, microcontrollers, and electronic circuits.
2. Interpret mechanical drawings, electrical schematics, and use CAD tools for mechatronic system design.
3. Develop programming skills for digital controllers, apply algorithms for system modeling, simulation, and optimization in mechatronic applications.

Course Outcomes

CO	CO Description
CO1	Demonstrate understanding of mechatronics system components and design principles.
CO2	Apply knowledge of hydraulic and pneumatic power transmission to design components.
CO3	Design control strategies using programming languages and digital controllers.
CO4	Interpret and create mechanical drawings and electrical schematics for communication.
CO5	Apply critical thinking and problem-solving skills to hands-on projects and case studies.

CO-PO Mapping

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

Skills Acquired

- Knowledge on sensors and actuators
- Interface design
- Controller design and analysis
- Mechatronics system design approach

Mathematical Preliminaries

Basics of Microprocessor and Microcontroller, and basic programming skills

Unit 1 15 Hours

Fundamentals of Mechatronics System: Introduction to Mechatronics system - Key elements – Sensors and Actuators: Classification, principles of operation, and performance analysis. Controllers: Microprocessor and Microcontrollers: Overview, architecture, interfacing, and applications. ADC, DAC, V to I, I to P converters. PLC programming. Mechatronics Design process - Types of Design - Traditional and Mechatronics designs. Industrial design and ergonomics, safety - Man machine interface – Integrated product design - Advanced approaches in Mechatronics – Applications. CAD tools for mechatronic system design. Introduction to Virtual Instrumentation.

Unit 2 15 Hours

System Integration and validation: Introduction, Interface design - selection of interface cards-DAQ card-single channel-multichannal-RS232/422/485 communication- IEEE 488 standard interface-GUI card-GPIB-Ethernet switch, Field bus, Profibus, DeviceNet, HART. Mathematical modeling of mechatronic systems: DC Motor, 2R, 3R planner. Model development: Simulink, Sim mechanics. Model verification - Model validation - Model simulation. Control strategies and applications, Algorithm development and implementation.

Unit 3 **15 Hours**

Case Studies on Mechatronics System: Introduction, Machine Learning and AI in Mechatronics - Cantilever beam Force measurement system - Strain gauge weighing system - pH control system – Transducer calibration system - Controlling temperature of a hot/cold reservoir using PID – Control of pick and place robot – Robot trajectory and position control. Graphical System Design - Mechatronics control in Manufacturing. Application of concepts and principles in real-world projects.

Textbooks / References

1. Shetty, Devdas and Kolk, Richard A., "*Mechatronics System Design*", Thomson Learning / Vikas publishing house, New Delhi, 2010.
2. Bolton, "*Mechatronics – Electronic control systems in mechanical and electrical engineering*", 4th edition, Addison Wesley Longman Ltd., 2019.
3. Bishop, Robert H. *Mechatronics: an Introduction*. CRC Press, 2017.
4. Brian Morriss, "*Automated manufacturing Systems – Actuators Controls, sensors and Robotics*", McGraw Hill International Edition, 2000.
5. Bradley, D. Dawson, N.C.Burd and A.J. Loader, "*Mechatronics: Electronics in product and process*", Chapman and Hall, London, 1999.
6. Klaus Janschek, "*Mechatronic Systems Design*", Springer publisher, 2012.
7. Onwubolu, G., *Mechatronics: Principles and applications*. Elsevier, 2005.

24ED649 **INTRODUCTION TO DIGITAL TWIN** **3-0-0-3**

Course Objectives

1. To make students understand the conceptual framework and applications of digital twin technology.
2. Develop proficiency in digital twin modeling techniques, including data integration and simulation methodologies.
3. Evaluate the effectiveness, limitations, and ethical considerations of digital twin implementations in engineering design contexts.

Course Outcomes

CO	CO Description
CO1	Articulate the concept of digital twin and its significance in modern engineering design practices.
CO2	Demonstrate the ability to create and implement digital twin models for engineering systems, integrating data from various sources.
CO3	Design Digital Twins for discrete and process industries.
CO4	Evaluate the ethical, social, and environmental implications of digital twin technology in engineering design and propose responsible practices.
CO5	Communicate effectively about digital twin concepts, methodologies, and applications through written reports, presentations, and discussions.

CO-PO Mapping

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

Skills Acquired

- Knowledge on Digital Twins
- Model development and validation

Mathematical Preliminaries

Basic programming skills, Fundamentals of ML

Unit 1 **15 Hours**

Introduction to Digital Twins: Industrial Revolutions. Digital Twins: Definition, Types of Industry & its Requirements, Characteristics of Digital Twins, Importance, benefits, Impact, and Challenges. Conceptual design methodology of digital twins, Five-dimensional digital twins for the product, Application of Digital Twins in process, product, service industries, History of Digital Twins, Digital Transformation role in industry innovation, Technologies/tools enabling Digital Twins. Design of Digital Twins: Technological needs. Physics-based approach: Model identification, Model creation. Data-driven approach: Model development using ML/DL models. Digital twins for Prototype, Product, and Performance. Digital Twins validation.

Unit 2 **15 Hours**

Discrete Industry: Trends in the Discrete Industry, control system requirements in a Discrete Industry, Digital Twins of a Product, Digital Thread in Discrete Industry, Data Collection & Analysis for Product & production improvements, Automation Simulation, and Digital Enterprise. Process Industry: Basics of Process Industry, Trends in the process industry, control system requirements in a process industry, Digital Twins of a plant, Digital Thread in process Industry, Data collection & Analysis for process improvements, process safety, Automation simulation, and Digital Enterprise.

Unit 3 **15 Hours**

Applications of Digital Twins: Improvement in product quality, production process, process Safety, identifying bottlenecks and Improve efficiency, achieve flexibility in production, continuous prediction, and tuning of the production process through Simulation, reducing the time to market.

Advanced Topics and Future Directions: Emerging trends in digital twin technology, Integration with AI, machine learning, and blockchain, and the role of digital twins in smart manufacturing. Gen-AI for Digital Twins. Student presentations on research papers and projects related to digital twins.

Textbooks / References

1. Alp Ustundag and Emre Cevikcan, "*Industry 4.0: Managing The Digital Transformation*", Springer Series in Advanced Manufacturing., Switzerland, 2017.
2. Andrew Yeh Chris Nee, Fei Tao, and Meng Zhang, "*Digital Twin Driven Smart Manufacturing*", Elsevier Science., United States, 2019
3. Shyam Varan Nath, Pieter van Schalkwyk, Dan Isaacs, "*Building Industrial Digital Twins Design, Develop, and Deploy Digital Twin Solutions for Real-world Industries Using Azure Digital Twins*", Packt Publishing, 2021
4. Enis Karaarslan, Moharram Challenger, Ömer Aydin, Ümit Cali, "*Digital Twin Driven Intelligent Systems and Emerging Metaverse*", Springer Nature Singapore, 2023
5. Christoph Jan Bartodziej, "*The Concept Industry 4.0 An Empirical Analysis of Technologies and Applications in Production Logistics*", Springer Gambler., Germany, 2017.
6. Crespi, N., Drobot, A.T. and Minerva, R.,. *The Digital Twin: What and Why? In The Digital Twin* (pp. 3-20). Cham: Springer International Publishing. 2023
7. Farsi, M., Daneshkhah, A., Hosseinian-Far, A. and Jahankhani, H. eds. *Digital twin technologies and smart cities*. Berlin/Heidelberg, Germany: Springer. 2020

24ED650 **NOISE, VIBRATION AND HARSHNESS** **3-0-0-3**

Course Objectives

1. Introduce the importance of NVH analysis and associated standards in automobile industry
2. Familiarize students with the different sources of noise and vibration in automobiles
3. Enable the students to provide solutions to NVH problems through theoretical and experimental knowledge.
4. Familiarize on advanced techniques for reduction of NVH

Course Outcomes

CO	CO Description
CO1	Analyze vibrations of SDOF, MDOF and Continuous systems
CO2	Measure vibration and noise signals and evaluate them applying signal processing and analysis techniques including modal analysis
CO3	Apply Principles of NVH refinement in Vehicles and their systems – power train, chassis, body, suspension, etc.,
CO4	Evaluate acoustic materials and apply them for noise reduction
CO5	Apply advanced Techniques – NVH simulation, Statistical Energy Analysis, Acoustic Holography, beam forming, etc.,

CO-PO Mapping

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

Mathematical Preliminaries **3 Hours**

Basics of linear algebra – eigenvalue problems. Ordinary and partial differential equations.

Unit 1 **12 Hours**

Introduction to Automotive NVH-Fundamentals of vibrations –Vibration of Single degree of freedom, Multi degrees of freedom - Vehicle vibration measurement and analysis Fundamentals of acoustics, Acoustic Terminology, Sound Fundamentals, Plane Wave, Spherical Wave Propagation, Theories of Monopole & Di pole source, Sound Source, Transmission & Absorption, Absorption through multiple walls, Sound transmission through ducts, Structure Radiation, Sound level, sound field, sound wave equations, Octave bands, Helmholtz equation, Source path receiver models. Vehicle noise measurement, Noise Standards, Types of Signals, Signal conditioning and processing, Data Acquisition Systems, Analysis and presentation of data Ride Comfort – Sound Quality and psychoacoustics –Sound Quality Metrics, Subjective–objective correlation –Squeak and Rattle-Vibration isolation and Transmission.

Unit 2 **10 Hours**

Fourier series – Fourier Integrals –- Discrete Fourier Transforms – Fourier and Laplace Transforms - Filters - Windowing - Time Sampling and Aliasing - Random signal processing and analysis -Theory of modal analysis - Methods for performing modal analysis, Modal analysis of components, systems and vehicles Vehicle NVH refinement –Vehicle Development process - Target setting and Benchmarking

Unit 3 **10 Hours**

Refinement of Power train systems, Chassis and Suspension and Body –Vibro-acoustics – Aerodynamic noise and its refinement–Aeroacoustics Simulation methods in Automotive NVH – FEM and CFD, Vibro and Aeroacoustics, Cross functional optimization–Acoustic shielding and sound packages – Acoustic materials and their characterization - Active and semi-active noise control and their control systems and applications

Lab exercises **10 Hours**

1. Vibration measurement and Modal analysis
2. Use of sound level meter to measure cabin noise, radiated noise
3. Free and forced vibration analysis using the experimental setup.
4. Sound transmission loss analysis using simulation software
5. Noise source identification by masking method
6. Sound quality analysis – Jury rating, metrics and its correlation.

Textbooks / References

1. Xu Wang, "*Vehicle Noise and Vibration Refinement*", CRC Press Publication, 2016.
2. Norton M P, "*Fundamentals of Noise and Vibration*", 2nd Edition, Cambridge University Press,2003
3. M. L. Munjal, "*Noise and Vibration Control*", 2nd Edition, World Scientific Press: Singapore, 2024.
4. Anton Fuchs, Eugenius Nijman, Hans-Herwig Priebsch, "*Automotive NVH Technology*", springer, 2016.
5. Kihong Shin and Joseph K. Hammond "*Fundamentals of Signal Processing for Sound and Vibration Engineers*", Johe Wiley, 2008.

24ED651 **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

CO	CO Description
CO1	Familiarize with the statistical theories required for implementing robust design concepts in product development
CO2	Create designs that have minimal sensitivity to input variation
CO3	Perform sensitivity analysis and determine design parameters that have the largest impact on variation
CO4	Optimize design with multiple outputs
CO5	Create Empirical models to estimate system outputs

CO-PO Mapping

	PO1	PO2	PO3	P04	PO5
CO1	3	2	3	2	
CO2	3	2	3	2	
CO3	3	2	3	2	
CO4	3	2	3	2	
CO5	3	2	3	2	

Mathematical Preliminaries

Statistical distributions, process capability, and robustness concepts, tolerance analysis, and optimization techniques.

Unit 1 **17 Hours**

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.

Unit 2 **14 Hours**

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.

Unit 3 **14 Hours**

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.

24ED652 **FRACTURE AND FATIGUE** **3-0-0-3**

Course Objectives

1. Inculcate the fundamental principles of fracture mechanics
2. Develop a deep understanding of fatigue mechanisms
3. Apply Fracture and Fatigue Concepts in Design

Course Outcomes

CO	CO Description
CO1	Analyze fracture behavior in various materials and structures
CO2	Demonstrate proficiency in analyzing fatigue behavior
CO3	Apply fracture and fatigue principles to real-world engineering problems
CO4	Comprehend the standard and non-standard fracture mechanics tests to determine the fracture toughness
CO5	Identify the influencing factors in fatigue and understand how they relate to damage

CO-PO Mapping

	PO1	PO2	PO3	P04	PO5
CO1	3	2	1	3	2
CO2	3	2	1	2	2
CO3	3	2	1	3	3
CO4	3	2	1	3	2
CO5	3	2	1	2	2

Skills Acquired

- Understanding fracture mechanisms and experimental methods for measuring fracture toughness and crack behavior.
- Learning fatigue mechanisms, crack propagation theories, and techniques for toughening materials to mitigate fracture risks.
- Applying fracture mechanics principles in engineering design.

Mathematical Preliminaries **3 Hours**

Trigonometry, Algebra, Complex numbers and Calculus

Unit 1 **15 Hours**

Introduction, historic engineering failures, failure modes and propensity for fracture in different materials, linear elastic fracture mechanics (LEFM), Irwin's stress intensity factors, stress analysis of crack tips, experimental methods, plane strain and plane stress fracture toughness, Griffith theory and energy release rate, crack tip plasticity, mixed mode of fracture. Macroscopic theories in crack extension, instability and r-curves, application of fracture mechanics in design and materials development, toughening of materials, ductile and cleavage fracture, ductile-brittle transition, inter-granular fracture, environmentally assisted and time-dependent crack growth.

Unit 2 **15 Hours**

Fatigue, un-notched – stress-controlled fatigue, historical perspective on fatigue, fatigue characterization: total life versus defect tolerant philosophy, cyclic stress fields, notches, and short cracks, un-notched strain-controlled fatigue, fatigue crack propagation theories, crack closure phenomenon, microscopic theories of fatigue crack growth.

Unit 3 **15 Hours**

Notch effect and Notched Fatigue crack propagation, Fatigue testing methodologies, Fatigue crack growth resistance curves, Crack tip constraint under large scale yielding, variable amplitude loading, effect of corrosive media and temperature on fatigue, Fatigue from variable loading: spectrum loading, cumulative damage, load interaction, life calculation, Multiaxial Fatigue, Environmental fatigue, Damage Tolerance, Design Considerations, and Failure Analysis: Damage tolerance in materials, Design considerations for fatigue resistance, Methodologies for failure analysis.

Textbooks / References

1. Anderson, T.L., 2017. *Fracture mechanics: fundamentals and applications*. 4th Edition, CRC press.
2. Suresh, S., 2015. *Fatigue of materials*. 2nd Edition, Cambridge university press.
3. Stephens, R.I., Fatemi, A., Stephens, R.R. and Fuchs, H.O., 2012. *Metal fatigue in engineering*. 2nd Edition, John Wiley & Sons.
4. Broek, D., 2012. *Elementary engineering fracture mechanics*. Springer Science & Business Media.
5. Gdoutos, E.E., 2020. *Fracture mechanics: an introduction* (Vol. 263). Springer Nature.

24ED653 GEOMETRIC DIMENSIONING AND TOLERANCING 3-0-0-3

Course Objectives

1. Apply fundamental principles of GD&T for precise engineering communication.
2. Interpret and employ advanced techniques in specifying tolerances and datum reference frames.
3. Utilize digital tools and case studies to integrate GD&T into modern engineering practices.

Course Outcomes

CO	CO Description
CO1	Master GD & T symbols and apply GDT principles in engineering drawings.
CO2	Understanding the principles of tolerancing and application of tolerancing in industry practices.
CO3	Select Datum reference frames for various types of tolerancing methods.
CO4	Apply suitable tolerances, profile controls and measurement methods.

CO-PO Mapping

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

Skills Acquired

Knowledge of GD & T symbols and incorporation of the same for effective design communication.

Unit 1 10 Hours

Introduction and principles of GD & T: Importance of GD & T, scope and definitions, use of notes and symbol construction in GD&T, glossary and resource symbols and terms, feature control frame. Various units of measure and types of dimensioning, applications, advantages. Direct tolerancing methods and tolerance expression, interpretation of limits and tolerance accumulation, applicability of modifiers on geometric tolerance values, statistical tolerancing and modern industry practices.

Unit 2 10 Hours

Datum reference frames: Degrees of freedom and constrained features, datum reference in the feature control frame, primary, secondary, and tertiary datums, datum selection, multiple datum reference frames, datum targets and its applications, establishment of datum features and customized datum reference frames.

Form, Orientation, and Location Tolerances: Form control and specifying form tolerances, orientation control, symbols, and specifying orientation tolerances. Perpendicularity, parallelism, and angularity. Positional tolerancing fundamentals and pattern location, tolerancing for symmetrical relationships and coaxial feature controls. Runout: axial and radial, measurement.

Unit 3 10 Hours

Application of tolerances: Perpendicularity tolerance zones and applications, inspection of angularity. Angularity tolerance zones and applications, inspection. Parallelism tolerance zones, applications, inspection. Fundamental concepts of tolerance of position, zone of tolerance, cylinder-position, co-axiality, symmetry. Tolerance of position (TOP) control, true position tolerance, advantages and applications of TOP, regardless of feature size (RFS). Locating non-parallel holes.

Profile controls

Line, surface, profile tolerance zone specification, advantages of profile control, profile used to tolerance a polygon, conical feature, and coplanar surfaces.

Application of digital tools and industry standards.

Textbooks / References

1. Gene R. Cogorno, "*Geometric Dimensioning and Tolerancing for Mechanical Design*", 3rd edition, McGraw-Hill, 2020.
2. "*Dimensioning and Tolerancing*" (Based on Y14.5), ASME, 2009
3. Alex Krulikowski, "*Fundamentals of Geometric Dimensioning and Tolerancing 2018: Using Critical Thinking Skills*", Based on the ASME Y14.5-2018 Standard, Revised Edition, SAE International, 2021.
4. David A. Madsen and David P. Madsen, "*Geometric dimensioning and tolerancing*", Ninth edition, Goodheart-Willcox Co., 2012.
5. James D. Meadows, "*Geometric Dimensioning and Tolerancing*", Routledge, 2017.
6. Georg Henzold, "*Geometrical Dimensioning and Tolerancing for Design, Manufacturing and Inspection*", Elsevier, 2006.
7. Paul J. Drake, Jr., "*Dimensioning and Tolerancing Handbook*", McGraw-Hill, 1999.

23HU601	Career Competency I	L-T-P-C: 0-0-3-P/F

Prerequisite:
An open mind and the urge for self-development, basic English language skills and knowledge of high school level arithmetic.

Course Objectives:

- Help students transit from campus to corporate and enhance their soft skills
- Enable students to understand the importance of goal setting and time management skills
- Support them in developing their problem solving and reasoning skills
- Inspire students to enhance their diction, grammar and verbal reasoning skills

Course Outcomes:

CO1: Soft Skills - To develop positive mindset, communicate professionally, manage time effectively and set personal goals and achieve them.
CO2: Soft Skills - To make formal and informal presentations with self-confidence.
CO3: Aptitude - To analyze, understand and employ the most suitable methods to solve questions on arithmetic and algebra.
CO4: Aptitude - To analyze, understand and apply suitable techniques to solve questions on logical reasoning and data analysis.
CO5: Verbal - To infer the meaning of words and use them in the right context. To have a better understanding of the nuances of English grammar and become capable of applying them effectively.
CO6: Verbal - To identify the relationship between words using reasoning skills. To understand and analyze arguments and use inductive/deductive reasoning to arrive at conclusions and communicate ideas/perspectives convincingly.

CO-PO Mapping

PO/CO	PO1	PO2	PO3
CO1	2	1	-
CO2	2	1	-
CO3	2	1	-
CO4	2	1	-
CO5	1	2	-
CO6	2	2	-

Syllabus:

Soft Skills

Introduction to 'campus to corporate transition':
Communication and listening skills: communication process, barriers to communication, verbal and non-verbal communications, elements of effective communication, listening skills, empathetic listening, role of perception in communication.
Assertiveness skills: the concept, assertiveness and self-esteem, advantages of being assertive, assertiveness and organizational effectiveness.
Self-perception and self-confidence: locus of control (internal v/s external), person perception, social perception, attribution theories-self presentation and impression management, the concept of self and self-confidence, how to develop self-confidence.
Goal setting: the concept, personal values and personal goals, goal setting theory, six areas of goal setting, process of goal setting: SMART goals, how to set personal goals
Time management: the value of time, setting goals/ planning and prioritizing, check the time killing habits, procrastination, tools for time management, rules for time management, strategies for effective time management

Presentation skills: the process of presentation, adult learning principles, preparation and planning, practice, delivery, effective use of voice and body language, effective use of audio visual aids, dos and don'ts of effective presentation

Public speaking-an art, language fluency, the domain expertise (Business GK, Current affairs), self-confidence, the audience, learning principles, body language, energy level and conviction, student presentations in teams of five with debriefing

Verbal

Vocabulary: Familiarize students with the etymology of words, help them realize the relevance of word analysis and enable them to answer synonym and antonym questions. Create an awareness about the frequently misspelt words, commonly confused words and wrong form of words in English.

Grammar: Train students to understand the nuances of English Grammar and thereby enable them to spot grammatical errors and punctuation errors in sentences.

Reasoning: Stress the importance of understanding the relationship between words through analogy questions and learn logical reasoning through syllogism questions. Emphasize the importance of avoiding the gap (assumption) in arguments/ statements/ communication.

Oral Communication Skills: Aid students in using the gift of the gab to improve their debating skills.

Writing Skills: Introduce formal written communication and keep the students informed about the etiquettes of email writing. Make students practise writing emails especially composing job application emails.

Aptitude

Numbers: Types, Power Cycles, Divisibility, Prime, Factors & Multiples, HCF & LCM, Surds, Indices, Square roots, Cube Roots and Simplification.

Percentage: Basics, Profit, Loss & Discount, and Simple & Compound Interest.

Ratio, Proportion & Variation: Basics, Alligations, Mixtures, and Partnership.

Averages: Basics, and Weighted Average.

Time and Work: Basics, Pipes & Cistern, and Work Equivalence.

Time, Speed and Distance: Basics, Average Speed, Relative Speed, Boats & Streams, Races and Circular tracks.

Statistics: Mean, Median, Mode, Range, Variance, Quartile Deviation and Standard Deviation.

Data Interpretation: Tables, Bar Diagrams, Line Graphs, Pie Charts, Caselets, Mixed Varieties, and other forms of data representation.

Equations: Basics, Linear, Quadratic, Equations of Higher Degree and Problems on ages.

Logarithms, Inequalities and Modulus: Basics

References

Soft Skills:

Communication and listening skills:

- Andrew J DuRbin , "Applied Psychology: Individual and organizational effectiveness", Pearson-Merril Prentice Hall, 2004
- Michael G Aamodt, "An Applied Approach, 6th edition", Wadsworth Cengage Learning, 2010

Assertiveness skills:

- Robert Bolton, Dorothy Grover Bolton, "People Style at Work..and Beyond: Making Bad Relationships Good and Good", Ridge Associates Inc., 2009
- John Hayes "Interpersonal skills at work", Routledge, 2003
- Nord, W. R., Brief, A. P., Atieh, J. M., & Doherty, E. M., "Meanings of occupational work: A collection of essays (pp. 21- 64)", Lexington, MA: Lexington Books, 1990

Self-perception and self-confidence:

- Mark J Martinko, "Attribution theory: an organizational perspective", St. Lucie, 1995
- Miles Hewstone, "Attribution Theory: Social and Functional Extensions", Blackwell, 1983

Time management:

- Stephen Covey, "The habits of highly effective people", Free press Revised edition, 2004
- Kenneth H Blanchard , "The 25 Best Time Management Tools & Techniques: How to Get More Done Without Driving Yourself Crazy" , Peak Performance Press, 1st edition 2005

- Kenneth H. Blanchard and Spencer Johnson, “The One Minute Manager” , William Morrow, 1984

Verbal:

- Erica Meltzer, “The Ultimate Guide to SAT Grammar”
- Green, Sharon, and Ira K. Wolf, “Barron's New GRE”, Barron's Educational Series, 2011
- Jeff Kolby, Scott Thornburg & Kathleen Pierce, “Nova’s GRE Prep Course”
- Kaplan, “Kaplan New GRE Premier”, 2011-2012
- Kaplan’s GRE Comprehensive Programme
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Aptitude:

- Arun Sharma, “How to Prepare for Quantitative Aptitude for the CAT Common Admission Test”, Tata Mc Graw Hills, 5th Edition , 2012
- Arun Sharma, “How to Prepare for Logical Reasoning for the CAT Common Admission Test”, Tata Mc Graw Hills, 2nd Edition, 2014
- Arun Sharma, “How to Prepare for Data Interpretation for the CAT Common Admission Test”, Tata Mc Graw Hills, 3nd Edition, 2015
- R.S. Aggarwal, “Quantitative Aptitude For Competitive Examinations”, S. Chand Publishing, 2015
- R.S. Aggarwal, “A Modern Approach To Verbal & Non-Verbal Reasoning”, S. Chand Publishing, Revised -2015
- Sarvesh Verma, “Quantitative Aptitude-Quantum CAT”, Arihant Publications, 2016
- www.mbatious.com
- www.campusgate.co.in
- www.careerbless.com

Evaluation Pattern

Assessment	Internal	External
Continuous Assessment (CA)* – Soft Skills	30	-
Continuous Assessment (CA)* – Aptitude	10	25
Continuous Assessment (CA)* – Verbal	10	25
Total	50	50
Pass / Fail		

*CA - Can be **presentations, speaking activities and tests.**

23HU611	Career Competency II	L-T-P-C:

Pre-requisite: Willingness to learn, team spirit, basic English language and communication skills and knowledge of high school level arithmetic.

Course Objectives:

- Help students to understand the importance of interpersonal skills and team work
- Prepare the students for effective group discussions and interviews participation.
- Help students to sharpen their problem solving and reasoning skills
- Empower students to communicate effectively by using the correct diction, grammar and verbal reasoning skills

Course Outcomes:

CO1: Soft Skills - To demonstrate good interpersonal skills, solve problems and effectively participate in group discussions.

CO2: Soft Skills - To write technical resume and perform effectively in interviews.

CO3: Aptitude - To identify, investigate and arrive at appropriate strategies to solve questions on arithmetic by managing time effectively.

CO4: Aptitude - To investigate, understand and use appropriate techniques to solve questions on logical reasoning and data analysis by managing time effectively.

C05: Verbal - To be able to use diction that is more refined and appropriate and to be competent in knowledge of grammar to correct/improve sentences

C06: Verbal - To be able to examine, interpret and investigate passages and to be able to generate ideas, structure them logically and express them in a style that is comprehensible to the audience/recipient.

CO-PO Mapping

PO/CO	PO1	PO2	PO3
CO1	2	1	-
CO2	2	1	-
CO3	2	1	-
CO4	2	1	-
CO5	1	2	-
CO6	2	2	-

Syllabus

Soft Skills

Interpersonal skill: ability to manage conflict, flexibility, empathetic listening, assertiveness, stress management, problem solving, understanding one's own interpersonal needs, role of effective team work in organizations

Group problem solving: the process, the challenges, the skills and knowledge required for the same.

Conflict management: the concept, its impact and importance in personal and professional lives, (activity to identify personal style of conflict management, developing insights that helps in future conflict management situations.)

Team building and working effectively in teams: the concept of groups (teams), different stages of group formation, process of team building, group dynamics, characteristics of effective team, role of leadership in team effectiveness. (Exercise to demonstrate the process of emergence of leadership in a group, debrief and reflection), group discussions.

Interview skills: what is the purpose of a job interview, types of job interviews, how to prepare for an interview, dos and don'ts of interview, One on one mock interview sessions with each student

Verbal

Vocabulary: Help students understand the usage of words in different contexts. Stress the importance of using refined language through idioms and phrasal verbs.

Grammar: Enable students to identify poorly constructed sentences or incorrect sentences and improvise or correct them.

Reasoning: Facilitate the student to tap her/his reasoning skills through critical reasoning questions and logical ordering of sentences.
Reading Comprehension: Enlighten students on the different strategies involved in tackling reading comprehension questions.
Public Speaking Skills: Empower students to overcome glossophobia and speak effectively and confidently before an audience.
Writing Skills: Practice closet tests that assess basic knowledge and skills in usage and mechanics of writing such as punctuation, basic grammar and usage, sentence structure and rhetorical skills such as writing strategy, organization, and style.

Aptitude
Sequence and Series: Basics, AP, GP, HP, and Special Series.
Geometry: 2D, 3D, Coordinate Geometry, and Heights & Distance.
Permutations & Combinations: Basics, Fundamental Counting Principle, Circular Arrangements, and Derangements.
Probability: Basics, Addition & Multiplication Theorems, Conditional Probability and Bayes' Theorem.
Logical Reasoning I: Arrangements, Sequencing, Scheduling, Venn Diagram, Network Diagrams, Binary Logic, and Logical Connectives, Clocks, Calendars, Cubes, Non-Verbal reasoning and Symbol based reasoning.
Logical Reasoning II: Blood Relations, Direction Test, Syllogisms, Series, Odd man out, Coding & Decoding, Cryptarithmetic Problems and Input - Output Reasoning.
Data Sufficiency: Introduction, 5 Options Data Sufficiency and 4 Options Data Sufficiency.
Campus recruitment papers: Discussion of previous year question papers of all major recruiters of Amrita Vishwa Vidyapeetham.
Miscellaneous: Interview Puzzles, Calculation Techniques and Time Management Strategies.

References
Soft Skills
Team Building
- Thomas L.Quick, "Successful team building", AMACOM Div American Mgmt Assn, 1992
- Brian Cole Miller, "Quick Team-Building Activities for Busy Managers: 50 Exercises That Get Results in Just 15 Minutes", AMACOM; 1 edition, 2003.
- Patrick Lencioni, "The Five Dysfunctions of a Team: A Leadership Fable", Jossey-Bass, 1st Edition, 2002

Verbal
- "GMAT Official Guide" by the Graduate Management Admission Council, 2019
- Arun Sharma, "How to Prepare for Verbal Ability And Reading Comprehension For CAT"
- Joern Meissner, "Turbocharge Your GMAT Sentence Correction Study Guide", 2012
- Kaplan, "Kaplan GMAT 2012 & 13"
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- Manhattan Prep, "Critical Reasoning 6th Edition GMAT"
- Manhattan Prep, "Sentence Correction 6th Edition GMAT"
- Mike Barrett "SAT Prep Black Book The Most Effective SAT Strategies Ever Published"
- Mike Bryon, "Verbal Reasoning Test Workbook Unbeatable Practice for Verbal Ability, English Usage and Interpretation and Judgement Tests"
- www.bristol.ac.uk/arts/skills/grammar/grammar_tutorial/page_55.htm
- www.campusgate.co.in

Aptitude
- Arun Sharma, "How to Prepare for Quantitative Aptitude for the CAT Common Admission Test", Tata Mc Graw Hills, 5th Edition, 2012

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22AVP103 Mastery Over Mind (MAOM) 1-0-2 2

1. Course Overview

Master Over the Mind (MAOM) is an Amrita initiative to implement schemes and organise university-wide programs to enhance health and wellbeing of all faculty, staff, and students (UN SDG -3). This program as part of our efforts for sustainable stress reduction gives an introduction to immediate and long-term benefits and equips every attendee to manage stressful emotions and anxiety facilitating inner peace and harmony.

With a meditation technique offered by Amrita Chancellor and world-renowned humanitarian and spiritual leader, Sri Mata Amritanandamayi Devi (Amma), this course has been planned to be offered to all students of all campuses of AMRITA, starting off with all first years, wherein one hour per week is completely dedicated for guided practical meditation session and one hour on the theory aspects of MAOM. The theory section comprises lecture hours within a structured syllabus and will include invited guest lecture series from eminent personalities from diverse fields of excellence. This course will enhance the understanding of experiential learning based on university's mission: "Education for Life along with Education for Living", and is aimed to allow learners to realize and rediscover the infinite potential of one's true Being and the fulfilment of life's goals.

2. Course Syllabus

Unit 1 (4 hours)

Causes of Stress: The problem of not being relaxed. Need for meditation -basics of stress management at home and workplace. Traditions and Culture. Principles of meditation– promote a sense of control and autonomy in the Universal Human Value System. Different stages of Meditation. Various Meditation Models. Various practices of Meditation techniques in different schools of philosophy and Indian Knowledge System.

Unit 2 (4 hours)

Improving work and study performance. Meditation in daily life. Cultivating compassion and good mental health with an attitude of openness and acceptance. Research and Science of Meditation: Significance of practising meditation and perspectives from diverse fields like science, medicine, technology. philosophy, culture, arts, management, sports, economics, healthcare, environment etc. The role of meditation for stress and anxiety reduction in one's life with insights based on recent cutting-edge technology. The effect of practicing meditation for the wholesome wellbeing of an individual.

Unit 3 (4 hours)

Communications: principles of conscious communication. Relationships and empathy: meditative approach in managing and maintaining better relationships in life during the interactions in the world, role of MAOM in developing compassion, empathy and responsibility, instilling interest, and orientation to humanitarian projects as a key to harness intelligence and compassion in youth. Methodologies to evaluate effective awareness and relaxation gained from meditation. Evaluating the global transformation through meditation by instilling human values which leads to service learning and compassion driven research.

TEXT BOOKS:

1.Mata Amritanandamayi Devi, "Cultivating Strength and vitality," published by Mata Amritanandamayi Math, Dec 2019

2.Swami Amritaswarupananda Puri ,"The Color of Rainbow " published by MAM, Amritapuri.

REFERENCES:

1.Craig Groeschel, "Winning the War in Your Mind: Change Your Thinking, Change Your Life" Zondervan Publishers, February 2019

2.R Nagarathna et al, "New Perspectives in Stress Management "Swami Vivekananda Yoga Prakashana publications, Jan 1986

3. Swami Amritaswarupananda Puri "Awaken Children Vol 1, 5 and 7 - Dialogues with Amma on Meditation", August 2019
4. Swami Amritaswarupananda Puri "From Amma's Heart - Amma's answer to questions raised during world tours" March 2018
5. Secret of Inner Peace- Swami Ramakrishnananda Puri, Amrita Books, Jan 2018.
6. Mata Amritanandamayi Devi "Compassion :The only way to Peace:Paris Speech", MA Center, April 2016.

7. Mata Amritanandamayi Devi “Understanding and collaboration between Religions”, MA Center, April 2016.
8. Mata Amritanandamayi Devi “Awakening of Universal Motherhood: Geneva Speech” M A center, April 2016.

3. Evaluation and Grading

Internal			External	Total
Components	Weightage		Practical (attendance and class participation) 60%	100%
Quizzes(based on the reading material)	20%	40%		
Assignments (Based on webinars and lecture series)	20%			

4. Course Outcomes (CO)

CO1: Relate to the causes of stress in one’s life.
CO2: Experiment with a range of relaxation techniques
CO3: Model a meditative approach to work, study, and life.
CO4: Develop appropriate practice of MA-OM technique that is effective in one’s life
CO5: Inculcate a higher level of awareness and focus.
CO6: Evaluate the impact of a meditation technique

***Program Outcomes (PO) (As given by NBA and ABET)**
PO1: Engineering Knowledge
PO2: Problem Analysis
PO3: Design/Development of Solutions
PO4: Conduct Investigations of complex problems
PO5: Modern tools usage
PO6: Engineer and Society
PO7: Environment and Sustainability
PO8: Ethics
PO9: Individual & Team work
PO10: Communication
PO11: Project management & Finance
PO12: Lifelong learning

CO – PO Affinity Map

P O/ C O	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PS
CO 1	3	3	3	2		-	2	3	-	3	-	3	-	-	-
CO 2	3	3	3	2	2	_	2	3	3	3	-	3	-	-	-
CO 3	3	3	2	2	2	2	2	3	3	3	-	3	-	-	-
CO 4	3	3	3	2	-	2	3	3	3	3	-	3	-	-	-
CO 5	3	2	2	2	-	2	-	3	2	2	-	2	-	-	-
CO 6	3	2	2	2	3	2	_	3	2	2	-	2	-	-	-