SCHEME OF INSTRUCTION AND SYLLABI

Master of Engineering

A TWO YEAR (I-IV) PG PROGRAM

in

CAD/CAM

(AICTE Model Curriculum with effect from AY 2026-27)

(R–26 Regulation)

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY

(Autonomous Institution under UGC, Affiliated to Osmania University)

Department of Mechanical Engineering

Accredited by NBA and NAAC-UGC

Chaitanya Bharathi (Post), Gandipet, Hyderabad–500075

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY

OUR MOTTO: SWAYAM TEJASWIN BHAVA

VISION and MISSION of the INSTITUTE

Vision

To be the center of excellence in technical education and research

Mission

To address the emerging needs through quality technical education and advanced research

VISION and MISSION of the DEPT. of Mechanical Engineering

Vision

To be the destination for aspiring young minds to become globally competitive, enlightened, innovative, immediate contributors to the industry and successful in higher studies in the field of mechanical engineering.

Mission

1. To impart quality and innovative education in mechanical engineering with basic and specialized Training, internships to meet the current and emerging needs of the industry.
2. To prepare the students for successful professional career by inculcating ethical, entrepreneurial and leadership qualities.
3. To foster Research and Development environment by disseminating knowledge and technology by involving the students in publications, sponsored projects and consultancy.

DEPARTMENT OF MECHANICAL ENGINEERING

Program Educational Objectives of M.E (CAD/CAM) Program

PE01 Graduates will become professional contributors in the industry related to the area of CAD/CAM.

PE02 Graduates will excel in Research, Development and Consultancy.

PE03 Graduates will become Entrepreneurs in CAD/CAM industry.

Program Outcomes of M.E (CAD/CAM) Program

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

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

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

PO4 Recognize state-of-the-art advancements in sustainable technologies, and engage in life-long learning to address emerging industrial challenges.

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY
R26 (In line with AICTE Model Curriculum) with effect from AY 2026-27

M.E. (CAD/CAM)

SEMESTER – I

S.no	Course Code	Title of the Course	Scheme of Instruction			Scheme of Examination			Credits
			Hours Per Week			Duration of SEE in Hours	Maximum Marks		
			L	T	P/D		CIE	SEE	
THEORY									
1	26MEC101	Advanced Computer Aided Design	3	--	--	3	40	60	3
2	26MEC102	Digital Manufacturing	3	--	--	3	40	60	3
3		Programme Elective – I	3	--	--	3	40	60	3
4		Programme Elective - II	3	--	--	3	40	60	3
5	26MEM101	Research Methodology and IPR	2	--	--	3	40	60	2
6		Audit Course – 1	2	--	--	2	--	50	Non-Credit
PRACTICALS									
7	26MEC103	Advanced Computer Aided Design Lab	--	--	2	--	50	--	1
8	26MEC104	Digital Manufacturing Lab	--	--	2	--	50	--	1
9	26MEC105	Vibrations and Condition Monitoring Lab			2		50		1
Total			**16**	--	**6**	**17**	**350**	**350**	**17**
Clock Hours Per Week: 22									

L: Lecture **D: Drawing** **CIE: Continuous Internal Evaluation**

T: Tutorial **P: Practical/Project Seminar/Dissertation** **SEE: Semester End Examination**

Program Elective - I		Program Elective - II	
26MEE101	Computer Aided Product Design	26MEE104	Computer Integrated Manufacturing
26MEE102	Vibration Analysis and Machine Condition Monitoring	26MEE105	Quality & Reliability Engineering
26MEE103	Smart Materials and Structures	26MEE106	Industrial Robotics and Artificial Intelligence

Audit Course - I		
S.no	**Subject Code**	**Name of the Subject**
1	26CEA101	Disaster Mitigation and Management
2	26EEA101	Sanskrit For Computational Thinking And Engineering Applications
3	26ECA101	Value Education
4	26ADA101	Pedagogy Studies
5	26EGA101	English for Research Paper Writing
6	26EGA102	Indian Constitution and Fundamental Rights
7	26EGA103	Stress Management by Yoga
8	26EGA104	Personality Development through Life's Enlightenment Skills

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY

R26 (In line with AICTE Model Curriculum) with effect from AY 2026-27

M.E. (CAD/CAM)

SEMESTER – II

S.no	Course Code	Title of the Course	Scheme of Instruction			Scheme of Examination			Credits
			Hours Per Week			Duration of SEE in Hours	Maximum Marks		
			L	T	P/D		CIE	SEE	
THEORY									
1	26MEC106	Finite Element Methods and Applications	3	--	--	3	40	60	3
2	26MEC107	Mechanical Design and Analysis	3	--	--	3	40	60	3
3	26MEC108	Manufacturing and Mechanics of Composite Materials	3	--	--	3	40	60	3
4		Program Elective - III	3	--	--	3	40	60	3
5		Program Elective - IV	3	--	--	3	40	60	3
PRACTICALS									
6	26MEC109	Computer Aided Engineering Lab	--	--	3	--	50	--	1.5
7	26MEC110	Mechanical Design and Analysis Laboratory	--	--	3	--	50	--	1.5
8	26MEC111	Mini Project with Seminar	--	--	2	--	50	--	1
Total			**15**	--	**8**	**15**	**350**	**300**	**19**
Clock Hours Per Week: 23									

L: Lecture **D: Drawing** **CIE: Continuous Internal Evaluation**

T: Tutorial **P: Practical/Project Seminar/Dissertation** **SEE: Semester End Examination**

Program Elective - III		Program Elective - IV	
26MEE107	Computational Methods in Engineering	26MEE110	Digital Twin and Industry 5.0
26MEE108	Advanced Optimization Techniques	26MEE111	Design for Manufacturing and Assembly
26MEE109	Fracture Mechanics	26MEE112	Machine Learning for Intelligent Systems

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY

R26 (In line with AICTE Model Curriculum) with effect from AY 2026-27

M.E. (CAD/CAM)

SEMESTER – III

S.no	Course Code	Title of the Course	Scheme of Instruction			Scheme of Examination			Credits
			Hours Per Week			Duration of SEE in Hours	Maximum Marks		
			L	T	P/D		CIE	SEE	
THEORY									
1		Program Elective -V	3	--	--	3	40	60	3
2		Open Elective	3	--	--	3	40	60	3
3		Audit Course-2	2	--	--	2	--	50	Non - Credit
DISSERTATION									
4	26MEC112	Industrial Project / Dissertation Phase I	--	--	20	--	100	--	10
Total			**8**	**--**	**20**	**8**	**180**	**170**	**16**
Clock Hours Per Week: 28									

L: Lecture **D: Drawing** **CIE: Continuous Internal Evaluation**

T: Tutorial **P: Practical/Project Seminar/Dissertation** **SEE: Semester End Examination**

Program Elective - V		Open Electives	
26MEE113	Design For Sustainability and Safety	26CEO101	Cost Management of Engineering Projects
26MEE114	Automation In Manufacturing	26EEO104	Waste to Energy
26MEE115	Design Thinking and Process Planning	26CSO101	Business Analytics

Audit Course - II		
S.no	**Subject Code**	**Name of the Subject**
1	26CEA101	Disaster Mitigation and Management
2	26EEA101	Sanskrit For Computational Thinking And Engineering Applications
3	26ECA101	Value Education
4	26ADA101	Pedagogy Studies
5	26EGA101	English for Research Paper Writing
6	26EGA102	Indian Constitution and Fundamental Rights
7	26EGA103	Stress Management by Yoga
8	26EGA104	Personality Development through Life's Enlightenment Skills

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M.E. (CAD/CAM)

SEMESTER – IV

S.no	Course Code	Title of the Course	Scheme of Instruction			Scheme of Examination			Credits
			Hours Per Week			Duration of SEE in Hours	Maximum Marks		
			L	T	P/D		CIE	SEE	
THEORY									
9	26MEC113	Industrial Project / Dissertation Phase- II	--	--	32	Viva voce	100	100	16
Total			--	--	32	--	**100**	**100**	**16**
Clock Hours Per Week: 32									

L: Lecture **D: Drawing** **CIE: Continuous Internal Evaluation**

T: Tutorial **P: Practical/Project Seminar/Dissertation** **SEE: Semester End Examination**

Open Electives offered by Mechanical Engineering		
S.no	**Course code**	**Title of the Course**
1	26MEO 101	Industrial Safety
2	26MEO 102	Introduction to Optimization Techniques
3	26MEO 103	Composite Materials
4	26MEO 104	Alternative energy sources
5	26MEO 105	Computational Fluid Dynamics
6	26MEO 106	Design Thinking For Business Solutions

List of Subjects for ME (CAD/CAM) Course with specialization in CAD/CAM

S.No.	Course Code	Title of the Course
Program Core Courses		
1	26MEC101	Computer Aided Modeling and Design
2	26MEC102	Digital Manufacturing
3	26MEC106	Finite Element Techniques
4	26MEC107	Mechanical Design and Analysis
5	26MEC108	Mechanics of Composite Materials
Practical Courses / Mini Project with Seminar/ Dissertation		
6	26MEC103	Advanced Computer Aided Design Lab
7	26MEC104	Digital Manufacturing Lab
8	26MEC105	Vibrations and Condition Monitoring Lab
9	26MEC109	Computer Aided Engineering Lab
10	26MEC110	Mechanical Design and Analysis Lab
11	26MEC111	Mini Project with Seminar
12	26MEC112	Industrial Project / Dissertation Phase - I
13	26MEC113	Industrial Project / Dissertation Phase - II
Program Elective Courses		
Program Elective – I Courses		
1	26MEE101	Computer Aided Product Design
2	26MEE102	Vibration Analysis and Machine Condition Monitoring
3	26MEE103	Smart Materials and Structures
		Program Elective – II Courses
4	26MEE104	Computer Integrated Manufacturing
5	26MEE105	Quality & Reliability Engineering
6	26MEE106	Industrial Robotics and Artificial Intelligence
Program Elective – III Courses		
7	26MEE107	Computational Methods in Engineering
8	26MEE108	Advanced Optimization Techniques
9	26MEE109	Fracture Mechanics
Program Elective – IV Courses		
10	26MEE110	Digital Twin and Industry 5.0
11	26MEE111	Design for Manufacturing and Assembly
12	26MEE112	Machine Learning for Intelligent Systems

Program Elective – V Courses		
13	26MEE113	Design For Sustainability and Safety
14	26MEE114	Automation In Manufacturing
15	26MEE115	Design Thinking and Process Planning
		Mandatory Course
1	26MEM101	Research Methodology and IPR
Audit Courses		
1	26CEA101	Disaster Mitigation and Management
2	26EEA101	Sanskrit For Computational Thinking And Engineering Applications
3	26ECA101	Value Education
4	26ADA101	Pedagogy Studies
5	26EGA101	English for Research Paper Writing
6	26EGA102	Constitution of India
7	26EGA103	Stress Management by Yoga
8	26EGA104	Personality Development through Life's Enlightenment Skills
Open Elective Courses		
1	26CEO101	Cost Management of Engineering Projects
2	26EEO104	Waste to Energy
3	26CSO101	Business Analytics
Service Courses Offered by Mechanical Engineering Department		
1	26MEO101	Industrial Safety
2	26MEO102	Introduction to Optimization Techniques
3	26MEO103	Composite Materials
4	26MEO104	Alternative energy sources
5	26MEO105	Computational methods
6	26MEO 106	Design Thinking For Business Solutions

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M.E. (CAD/CAM)

SEMESTER – I

S.no	Course Code	Title of the Course	Scheme of Instruction			Scheme of Examination			Credits
			Hours Per Week			Duration of SEE in Hours	Maximum Marks		
			L	T	P/D		CIE	SEE	
THEORY									
1	26MEC101	Advanced Computer Aided Design	3	--	--	3	40	60	3
2	26MEC102	Digital Manufacturing	3	--	--	3	40	60	3
3		Programme Elective – I	3	--	--	3	40	60	3
4		Programme Elective - II	3	--	--	3	40	60	3
5	26MEM101	Research Methodology and IPR	2	--	--	3	40	60	2
6		Audit Course – 1	2	--	--	2	--	50	Non-Credit
PRACTICALS									
7	26MEC103	Advanced Computer Aided Design Lab	--	--	2	--	50	--	1
8	26MEC104	Digital Manufacturing Lab	--	--	2	--	50	--	1
9	26MEC105	Vibrations and Condition Monitoring Lab			2		50		1
Total			**16**	--	**6**	**17**	**350**	**350**	**17**
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Program Elective - I		Program Elective - II	
26MEE101	Computer Aided Product Design	26MEE104	Computer Integrated Manufacturing
26MEE102	Vibration Analysis and Machine Condition Monitoring	26MEE105	Quality & Reliability Engineering
26MEE103	Smart Materials and Structures	26MEE106	Industrial Robotics and Artificial Intelligence

Audit Course - I		
S.no	**Subject Code**	**Name of the Subject**
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3	26ECA101	Value Education
4	26ADA101	Pedagogy Studies
5	26EGA101	English for Research Paper Writing
6	26EGA102	Indian Constitution and Fundamental Rights
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8	26EGA104	Personality Development through Life's Enlightenment Skills

26MEC101

ADVANCED COMPUTER AIDED DESIGN

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:
This course aims to:
1. Provide the basics of computer aided design.
2. Familiarize the student with the knowledge on design process.
3. Explain the uses of wireframe and surface entities.
4. Familiarize the student various geometric transformations.
5. Understand various advanced modeling concepts.

Course Outcomes:
Upon completion of this course, students will be able to:
1. Understand the design process, visualize models through graphics standards and apply principles of computer graphics like geometric transformations, windowing and clipping.
2. Recognize various wireframe entities and model them.
3. Apply surface modelling techniques for generating various parts
4. Differentiate various solid modelling techniques
5. Understand various advanced modelling concepts like parametric and variational modelling, feature based design, interference detection

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	1	2	2
CO2	2	1	2	2
CO3	3	2	3	2
CO4	3	2	3	2
CO5	3	1	3	2

UNIT - I
Introduction: Design process, Design criteria, Geometric Modelling, Iterative Design, CAD process
Geometric Transformations: 2D & 3D Transformations, Homogeneous Coordinates, Concatenated Transformations, Windowing - View ports -Clipping transformations
Graphics Standards: GKS, IGES, PDES and their relevance

UNIT – II
Modeling of Curves: Curve representation, Analytic curves- Lines, and Circles, Ellipse, and Conics, Synthetic curves – Cubic, Bezier, B-Splines, and Non Uniform Rational B-Splines. Curve Manipulations

UNIT- III
Surface Modeling: Surface representation, Analytic Surfaces: Plane Surface, Ruled Surface, Surface of Revolution, Tabulated Cylinder. Synthetic Surface: Cubic, Bezier, B-spline, Coons surface, Surface Manipulations

UNIT - IV

Solid Modeling Techniques: Geometry and Topology, Solid Entities, Solid Representation, Fundamentals of Solid Modeling**,** Boundary Representation (B-rep) & Constructive Solid Geometry (CSG), Boolean Models, Primitive Instancing, Cell Decomposition & Spatial Occupancy Enumeration.

UNIT - V

Advanced Modelling Concepts: Feature Based Modeling, Assembly Modeling, Conceptual Design and Top down design, Parametric and Variational Modeling, Feature recognition, Design by Features, Interference Detection by Motion analysis

Text Books:

1. Ibrahim Zeid, "CAD/CAM Theory and Practice", Mc Graw Hill, 1998.
2. Foley, Van Dam, Feiner and Hughes, "Computer Graphics Principles and Practice", 2 /e., Addison Wesley, 2000.

Suggested Reading:

1. E. Michael, "Geometric Modelling", John Wiley & Sons, 1995.
2. Hill Jr, F.S.,"Computer Graphics using open GL", Pearson Education, 2003.

26MEC102

DIGITAL MANUFACTURING

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:

This course aims to

1. Provide the importance of digital Manufacturing in the current scenario.
2. Make students Gain the knowledge of Cyber-physical systems and functionality
3. Provide the Comparison and applications of Subtractive and Additive Manufacturing Processes.
4. Provide concepts of Product life cycle, Product data management system and Management information systems
5. Familiarize the Reverse Engineering concepts Digital thread and Digital twin

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand the concept of digital manufacturing, technology and its potential in modern manufacturing process.
2. Recognize the role of cyber physical systems in digital manufacturing
3. Compare and select the subtractive and additive manufacturing processes for a given application.
4. Analyze the role of product life cycle and database management systems in manufacturing systems.
5. Understand the concepts of reverse engineering, digital thread and digital twins.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	1	1	-
CO2	2	-	2	-
CO3	2	-	2	-
CO4	2	1	2	1
CO5	2	1	2	1

UNIT – I

Introduction to digital manufacturing: Introduction to industrial revolutions, Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Smart and Connected Business Perspective, Smart Factories, digital manufacturing and its Global scenario. Impact on manufacturing careers, Operation Mode of Digital Manufacturing System, , Merits and demerits of digital Manufacturing systems.

UNIT – II

Cyber Physical Systems: Introduction. Sensing and Actuation. Next Generation Sensors, Augmented Reality and Virtual Reality, Role of artificial Intelligence and Big Data analytics in manufacturing. Need of cyber security in Industry 4.0, Basics of Industrial IoT and its scope

UNIT – III

Subtractive and Additive Manufacturing: Introduction, Comparison on the basis of application. Hardware : input devices, types of motors, encoders, drive mechanisms and controllers.

Additive Manufacturing Processes: Steriolithograhy, Fused deposition modelling, selective laser melting, direct metal deposition, and sheet lamination

UNIT –IV

Product database management systems: Types, Management information system, Manufacturing data preparation, Shop-floor control, Automatic identification systems (sensors, trackers)

Product life cycle management: Introduction, Types of Product Data, Product life cycle management (PLM) systems, integrated information systems in product lifecycle, Features of PLM System, System architecture, Product information models, Functionality of the PLM Systems.

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UNIT – V

Reverse engineering: Introduction, need of Reverse engineering process and basics steps involved. Application domain. Reverse engineering hardware and software.3D object scanning, Solid reconstruction from point cloud and tessellated data, downstream applications.

Digital design: Definition, Introduction, data storage and sharing in digital threads, Type of digital twins, tools and components of digital twins.

Text Books:

1. Fundamentals of Digital Manufacturing Science, by Z.Zhou,S.Xie, D. Chen, Springer, 2012.
2. Ibrahim Zeid and Sivasubramanian R, “CAD/CAM - Theory and Practice”,
3. Tata McGraw Hill Education, 2011.

Suggested Reading:

1. Vinesh Raja and Kiran J Fernandes, “Reverse Engineering- An Industrial Perspective”, Springer-Verlag, 2008.
2. Antti Saaksvuori and AnselmiImmonen, “Product Lifecycle Management”, Springer, 2004

26MEE101

COMPUTER-AIDED PRODUCT DESIGN

(Programme Elective – I)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Prerequisite: CAD/CAM

Course Objectives:

This course aims to cover:

1. To impart advanced mathematical and computational foundations for 3D modeling and computer graphics.
2. To develop proficiency in utilizing modern CAD systems, parametric modeling, and topology optimization.
3. To integrate product data management (PLM) strategies with Industry 4.0 data frameworks.
4. To apply simulation techniques (CAE/CFD) and smart manufacturing principles in product development.
5. To foster innovation through DFM, DFA, optimization algorithms, and sustainable design methodologies.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand the significanc of product design and manufacturing.
2. Apply prototyping techniques, concept generation methods, and concept testing approaches to develop, evaluate, and refine product designs using appropriate materials, tools, and customer feedback.
3. Apply PDM, PLM, and Industry 4.0 tools to manage product data, enable collaboration, and support secure, data-driven decisions across the product lifecycle.
4. Evaluate engineering designs using CAE/CFD simulation and integrate them with smart CAM/CNC processes.
5. Optimize product designs using DFM, DFA, rapid prototyping, and sustainable practices for modern manufacturing.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	3	2	1	1
CO 2	2	3	3	2
CO 3	1	2	2	2
CO 4	3	3	2	3
CO 5	2	2	3	2

UNIT – I

Introduction:

Significance of product design, product design and development process, sequential engineering design method, the challenges of product development, World Class manufacturing, Product definition, Engineering Design Process, Prototype Design and Innovation, Impact of Cost, Quality and time, Key Process Requirements for Rapid Prototyping..

UNIT - II

Prototyping: Product Prototyping, Prototype planning and management, Prototype cost estimation, Prototype Design Methods and tools. Materials Selection and Product Prototyping. Fundamentals of R.P. Classification of R.P. Processes.

Concept Generation: Activities of concept generation, clarifying problem, search both internally and externally, explore the output,

Concept Testing: Elements of testing: qualitative and quantitative methods including survey, measurement of

customers' response

UNIT – III

Product Data management and PLM:

Product Data Management (PDM) concepts, collaborative design frameworks, Product Lifecycle Management (PLM) strategies, Industry 4.0 integration, big data analytics in design, block chain for supply chain and data security, and the Digital Thread across enterprise systems.

UNIT - IV

CAE, Simulation & Smart Manufacturing:

Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), Computer-Aided Manufacturing (CAM), CNC machining, Digital Twin implementation, smart factories, and real-time IoT telemetry integration.

UNIT - V

Product Innovation & Optimization:

Design for Manufacturing (DFM), Design for Assembly (DFA), advanced design optimization, AR/VR in design review, sustainable and eco-friendly design principles, and Design for Additive Manufacturing (DfAM) constraints.

Text Books:

1. Biren Prasad, "Concurrent Engineering Fundamentals", Prentice Hall, 1st Edition, 1996.
2. James G. Bralla, "Product Design for Manufacturing", McGraw-Hill, 2nd Edition, 1999.
3. David F. Rogers and J. Alan Adams, "Mathematical Elements for Computer Graphics", McGraw-Hill, 2nd Edition, 1990.

Suggested Reading:

1. Rajesh Kumar Dhanaraj et al., "Digital Twin for Smart Manufacturing: Emerging Approaches and Applications", Springer, 1st Edition, 2023.
2. John Stark, "Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation", Springer, 3rd Edition, 2020.
3. M.P. Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, 3rd Edition, Pearson Education, 2007.

26MEE102

VIBRATION ANALYSIS AND MACHINE CONDITION MONITORING

(Programme Elective – I)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: Students will be able to:

1. To understand the fundamentals of mechanical vibrations, damping mechanisms, and free and forced vibration behavior of single and multi-degree freedom systems.
2. To analyze vibration characteristics of continuous systems such as strings, bars, and beams using analytical and modal analysis techniques.
3. To develop knowledge of maintenance engineering principles, machine condition monitoring, fault diagnosis, and reliability assessment methods.
4. To apply signal processing techniques such as Fourier analysis, FFT, filtering, modulation, and order analysis for vibration measurement and machinery diagnostics.
5. To evaluate faults in rotating machinery, bearings, gears, pumps, fans, motors, and industrial equipment using advanced condition monitoring and non-destructive testing techniques.

Outcomes: At the end of the course, a student will be able to

1. Analyze free and forced vibration responses of single and multi-degree freedom systems including damped and undamped systems.
2. Formulate and solve equations of motion for continuous and discrete vibrating systems using modal analysis and coordinate transformation techniques.
3. Apply maintenance strategies, FMECA, reliability concepts, and machine health monitoring techniques for industrial applications.
4. Perform vibration signal analysis using FFT, spectrum analysis, filtering, modulation, and data acquisition methods for fault identification.
5. Diagnose faults in rotating machinery, bearings, gears, pumps, fans, motors, and other mechanical systems using vibration analysis, oil analysis, and NDT techniques.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO1	3	2	2	1
CO2	3	2	3	1
CO3	2	2	2	3
CO4	3	2	2	2
CO5	3	2	3	3

UNIT – I Introduction: Single Degree of Freedom Systems. Free vibration response: Undamped, damped (viscously damped, logarithmic decrement, coulomb damping). Forced vibration response: Response of undamped systems to harmonic excitations, response of damped systems to harmonic excitations, response of damped systems to rotating unbalance, magnification factor, displacement transmissibility, force transmissibility, relative motion, vibration control–whirling of shafts.

UNIT – II Two Degree of Freedom Systems: Free and forced vibration response–Formulation of equation of motion (undamped, damped), Eigen values and Eigen vectors, modal matrix, normal modes, modes superposition, coordinate coupling, principal coordinates, decoupling of equations of motion, semi definite systems, self-excitation and stability analysis. **Vibrations of Continuous Systems**: Vibrations of strings, bars and beams, formulation of equations of motion, characteristic equations, identification of nodes and mode shapes.

UNIT – III Fundamentals of Maintenance, Vibrations and Signal Analysis: Introduction to maintenance principles including breakdown, preventive, predictive and condition-based maintenance. Reliability concepts, maintenance planning, FMECA, failure modes, root cause analysis and risk priority number. Machine health monitoring, fault detection and remaining useful life estimation. Experimental modal analysis, impact hammer and shaker testing, frequency response function and rotor dynamics. Rotor balancing, shaft misalignment, cracks and looseness. Time domain analysis including RMS, peak value, crest factor and kurtosis. Data acquisition, sampling theorem, aliasing, signal conditioning and analog/digital filters.

UNIT – IV Signal Processing and Monitoring Techniques: Fourier series, Fourier transform and Fast Fourier Transform (FFT) for spectrum analysis and fault frequency identification. Modulation, sideband analysis, order tracking and orbit analysis. Instrumentation for condition monitoring including accelerometers, displacement and temperature sensors. Data recording systems, vibration and noise monitoring, machine condition assessment, ISO vibration standards and acoustic analysis.

UNIT – V Machinery Diagnostics and Advanced Condition Monitoring: Condition monitoring of rotating machines and common faults such as imbalance, misalignment and looseness. Bearings and gear diagnostics including defect frequencies, envelope analysis and gear mesh frequency. Condition monitoring of fans, pumps and IC engines. Wear debris and oil analysis. Non-Destructive Testing (NDT) methods including dye penetrant, ultrasonic and eddy current testing. Industrial case studies, failure analysis and reliability improvement strategies.

Suggested Text books:

1. C. Sujatha, Vibration, Acoustics and Strain Measurement: Theory and Experiments. Cham, Switzerland: Springer International Publishing, 2023.
2. Theory of Vibrations with Applications by William T. Thomson and Marie Dillon Dahleh, 5th Edition, Prentice Hall, 1998
3. Machinery Condition Monitoring: Principles and Practices by Amiya Ranjan Mohanty, CRC Press, 2014.
4. Mechanical Fault Diagnosis and Condition Monitoring by R. Collacott, Chapman and Hall, 1977.
5. Practical Machinery Vibration Analysis and Predictive Maintenance by Cornelius Scheffer and Paresh Girdhar, Elsevier, 2004

Reference Books / Resources:

1. Digital Signal Processing by John G. Proakis, 4th Edition, Pearson Education, 2006.
2. Rotor Dynamics by J. S. Rao, 3rd Edition, New Age International Publishers, 1996.

26MEE103

SMART MATERIALS AND STRUCTURES

(Programme Elective – I)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: Students will be able to:

1. Study the basics of smart materials.
2. Analyze Constitutive Relationships.
3. Mathematical modeling for response of piezo beam.
4. Understand High-Band Width, Low Strain Smart Sensors**.**
5. Apply the smart materials to engineering problems.

Course Outcomes: At the end of the course, a student will be able to

1. Understand basics of smart materials and Analyze direct and reverse effect of piezo.
2. Understand and Evaluate Principles of Magnetostrictive materials and Active Smart Polymer.
3. Understand basics of SMA.
4. Analyze design of piezoelectric materials, Magnetostrictive and SMA.
5. Understand High-Band Width, Low Strain Smart Sensors, Intelligent Devices and self-healing.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO1	2	2	2	3
CO2	2	2	2	3
CO3	2	1	3	3
CO4	3	2	2	3
CO5	2	2	2	3

Unit-I

Smart Materials & Piezoelectric Materials: Introduction to Smart Material , difference between traditional and smart systems. Applications of Smart Material. Smart systems using Smart Material. Smart Actuators. Direct and Reverse Effects. Properties of few smart materials. History of Piezoelectricity. Polarization of Piezoelectric Materials. Constitutive equation of piezoelectricity. Piezoelectric constants and material properties, preparation of Piezoceramic Actuator. Piezoceramic Composites, Bimorphs & Piezostacks.

Nanomaterials: Classification of Nanomaterials, Nanoscale, bottom up and top down approaches, Applications

Unit II

Magnetostrictive Smart Materials & Active Smart Polymers:: Brief history of Magnetostriction, Some Examples. Technology features overview. Butterfly effect of TerFeNOL-D. Major Applicatons. Magnetostriction on solid rod. Magnetostrictive effects for actuation and sensing. The Constitutive equation of Magnetostrictive material, Magnetostrictive Mini Actuators Developed using Terfenol D (MMA) , Kiesewetter inch worm motor, Magnetostrictive Delay Line(MDL) Sensors Developed using Terfenol-D. Acive smart polymers, Classifications of Electro active Polymers, comparision between EAP and other smart materials. Actuators Developed using EAP, Sensors Developed using EAP. Ionic Polymer Metal Composite (IPMC). IPMC based actuators.

Unit III

Shape Memory Alloys (SMA): Shape memory effect, one way and two way shape memory effect. Comparative advantage of SMA, manufacturing of SMA. Stress-Strain behaviour at low temperature, hysteresis of SMA, pseudoelasticity. Vibration generation using SMA, SMA actuators. Sensors Developed using SMA and applications.

Unit IV

Modelling of smart materials: Fundamental equation of piezoelectricity. Piezoelectric Coefficients. A Comparison of Properties. Active Strain expression , Euler-Bernoulli Model , Uniform Strain Model of induced strain actuation Piezo actuators and sensors. Rainbow actuators, externally leverage systems. ISA Modelling for Magnetostrictive actuators. Modelling of shape memory alloy: Forward and reverse transformation, R phase transformation, Constitive model, Brinson model.

Unit V

High-Band Width, Low Strain Smart Sensors & Intelligent Devices based on Smart Materials: Piezoelectric smart Actuators , piezoelectric fuel injector. A Case history of Sensor Application. Introduction to MEMS Devices, MEMS based Accelerometers. Energy harvesting, design of energy harvesting. Concept of self-healing, mechanical healing,

Suggested Text books:

1. H. Abramovich, Intelligent Materials and Structures, 2nd ed. Berlin, Germany: De Gruyter, 2026
2. Brian Culshaw, Smart Structures and Materials, Artech House, 2000
3. Gauenzi, P., Smart Structures, Wiley, 2009
4. Cady, W. G., Piezoelectricity, Dover Publication.
5. Engineering Analysis of Smart Materials Systems by Donald J. Leo, John Wiley & Sons 2007.
6. Smart Materials Systems: Model Development by Ralph C. Smith, SIAM 2005.

Reference Books / Resources:

1. Smart Structural Theories by Inderjit Chopra & Jayant Sirohi, Cambridge University Press 2014.
2. A.V. Srinivasan, Smart Structures –Analysis and Design, 1st Edition, Cambridge University Press, New York, 2001.

26MEE104

COMPUTER INTEGRATED MANUFACTURING

(Programme Elective – II)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:

This course aims to

1. Provide the students' knowledge of the role of computers in manufacturing.
2. Provide an in-depth understanding of manufacturing and database systems.
3. Provide an understanding of the market needs and design the product.
4. Understand the students need of networking in the manufacturing industries.
5. Make students develop CIM systems for current manufacturing scenario by using advanced manufacturing concepts

Course Outcomes:

Upon completion of this course, students will be able to:

1. Select the modern tools and techniques for development of a product.
2. Use appropriate database systems for manufacturing a product and store the same for future use.
3. Apply the latest technology of manufacturing systems and software for the development of a product.
4. Use modern manufacturing techniques and tools including principles of networking.
5. Apply the concepts of lean manufacturing and Agile manufacturing.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	1	2	1
CO2	2	-	2	-
CO3	2	1	2	2
CO4	2	-	2	2
CO5	2	1	1	1

UNIT - I

Basic Concepts of CIM: The meaning of Manufacturing, Types of Manufacturing; CIM Definition, Elements of CIM, CIM wheel, concept or technology, Evolution of CIM, Benefits of CIM, Needs of CIM: Hardware and software. Fundamentals of Communication: Communications Matrix. Product Development Cycle, Concurrent Engineering: Definition, Sequential Engineering Versus Concurrent Engineering, Benefits of Concurrent Engineering, Characteristics of concurrent Engineering, Framework for integration of Life-cycle phases in CE, Concurrent Engineering Techniques, Integrated Product Development (IPD), Product Life-Cycle Management (PLM), and Collaborative Product Development.

UNIT - II

Introduction, Manufacturing Data: Types, sources; Database Terminology, Database requirements, Database models, Database Management System, DBMS Architecture, Query Language, Structural Query Language (SQL): Basic structure, Data definition Language (Create, Alter, Drop, Truncate, View), Data Manipulation Language (store, retrieve, update, delete). Illustration of Creating and Manipulating a Manufacturing Database. SQL as a Knowledge Base Query Language. Features of commercial DBMS: Oracle, MySQL, SQL Access,

Sybase, DB2. Product Data Management (PDM), Advantages of PDM.

UNIT- III

Product Design: Needs of the market, Design and Engineering, The design Process, Design for Manufacturability (DFM): Component Design, Design for Assembly. Computer-Aided Process Planning: Basic Steps in developing a process plan, Variant and Generative Process Planning, Feature Recognition in Computer-Aided Process Planning. Material Requirements Planning (MRP), Manufacturing Resource Planning (MRP –II), Cellular Manufacturing: Design of Cellular Manufacturing Systems, Cell Formation Approaches: Machine–Component Group Analysis, Similarity Coefficients-Based Approaches. Evaluation of Cell Design. Shop-floor Control: Data Logging and Acquisition, Automated Data Collection, Programmable Logic Controllers, Sensor Technology. Flexible Manufacturing Systems: Physical Components of an FMS. Types of Flexibility,

Layout Considerations: Linear Single Machine Layout, Circular Machine Layout, Cluster Machine Layout, Loop Layout; Operational Problems of FMS. FMS benefits

UNIT – IV

Introduction to Networking: Principles of Networking, Network Terminology, Types of Networks: LAN, MAN, WAN; Selection of Network Technology: Communication medium, Network Topology, Medium access control Methods, Signalling methods; Network Architectures and Protocols: OSI Model, MAP & TOP, TCP/IP, Network Interconnection and Devices, Network Performance. Framework for Enterprise-wide Integration.

CIM Models: ESPRIT-CIM OSA Model, NIST-AMRF Model, Siemens Model of CIM, Digital Equipment Corporation Model, IBM Concept of CIM.

UNIT – V

Advanced Manufacturing Systems: Holonic Manufacturing Systems, Reconfigurable Manufacturing Systems.

Lean Manufacturing: Definition, Principles of Lean Manufacturing, Characteristics of Lean Manufacturing, Value of Product, Continuous Improvement, Focus on Waste, Relationship of Waste to Profit, Four Functions of Lean Production, Performance Measures, The Supply Chain, Benefits of Lean Manufacturing. Introduction to Agile and Web Based Manufacturing systems. Concepts of e-Manufacturing.

Text Books:

1. S.Kant Vajpayee: “Principles of Computer Integrated Manufacturing”, Prentice HallIndia.
2. Nanua Singh: “Systems Approach to Computer Integrated Design and Manufacturing” , John Wiley.

Suggested Reading:

1. P.Radhakrishnan, S.Subramanyam: “CAD/CAM/CIM”, New Ag e International
2. Alavudeen, Venkateshwaran:“Computer Integrated Manufacturing”, Prentice HallIndia.

26MEE105

QUALITY AND RELIABILITY ENGINEERING

(Programme Elective – II)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:

To make the students to

1. Study the approaches and techniques to assess quality by statistical process control.
2. Study the methodology to assess and sampling of parameters
3. Impart knowledge in reliability concepts and assess the various configurations
4. Impart knowledge in reliability monitoring methods
5. Analyze effectively various techniques to improve reliability of the system.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Construct and modify complex 2D and 3D models using advanced CAD techniques such as parametric, feature-based, and assembly modeling
2. Explain the principles of lot-by-lot sampling and distinguish between single, double, and multiple sampling plans.
3. Apply reliability mathematics and probability concepts (a priori and a posteriori) to evaluate component and system reliability.
4. Evaluate and improve system reliability and maintainability by analyzing downtime, repair characteristics, availability, and maintenance strategies for engineering systems
5. Design and optimize systems using quality and reliability tools (DFQ, FMEA, DOE, Six Sigma) to improve performance and reliability.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	2	1	2
CO2	3	3	3	2
CO3	3	2	2	1
CO4	3	1	2	2
CO5	3	3	3	3

UNIT - I

Quality Concepts and Statistical Process Control : Quality definition, quality assurance, variation in processes, factors causing variation, process capability, tolerance design. Introduction to control charts: variables (X^{-}, R, and X^{-}–S charts), attributes (P, C, and U charts). Establishing and interpreting control charts, charts for variables, quality rating,short run SPC.

UNIT - II

Acceptance Sampling and Quality Assessment : Lot-by-lot sampling: types and probability of acceptance in single, double, and multiple sampling plans. Operating Characteristic (OC) curves, producer's risk and consumer's risk, concepts of AQL, LTPD, AOQL. Standard sampling plans for AQL and LTPD and their usage.

UNIT- III

Reliability Concepts and Monitoring: Definition of reliability, reliability mathematics and functions, hazard rate, design life, reliability measures, a priori and posteriori probabilities. Mortality of a component and mortality curve, useful life, redundancy, k-out-of-n systems, complex systems using Reliability Block Diagrams (RBD),

Bayes' approach, cut and tie sets, fault trees, standby systems.
Life testing methods: failure-terminated, time-terminated, and sequential testing. Reliability growth monitoring, reliability allocation, software reliability, and human reliability.

UNIT - IV

Reliability Improvement and Maintainability: Downtime analysis, repair time distribution, system repair time, maintainability prediction, maintainability measures. Inspection decisions, system availability, and strategies for improving system reliability and maintainability.

UNIT - V

Design for Quality, Reliability Engineering and Six Sigma: Design for Quality (DFQ) and Design for Reliability (DFR),Quality Function Deployment (QFD),Failure Modes and Effects Analysis (FMEA) and Failure Modes, Effects and Criticality Analysis (FMECA),Fault Tree Analysis (FTA) (advanced applications),Robust design concepts and Taguchi methods,Six Sigma methodology (DMAIC approach),Process capability improvement using Six Sigma,Design of Experiments (DOE) for quality improvement,Reliability-centered maintenance (RCM),Case studies in quality and reliability engineering

Text Books:

1. AmitavaMitra, "Fundamentals of Quality Control and Improvement", Pearson Education, 5th Edition, 2021
2. Charles E Ebling, "An Introduction to Reliability and Maintainability Engineering", Tata-McGraw Hill, Third Edition, 2019.
3. David J Smith, "Reliability, Maintainability and Risk: Practical Methods for Engineers", Butterworth,Tenth Edition, 2022.

Suggested Reading:

1. NPTEL – Introduction to Reliability Engineering (IIT Kharagpur, via Swayam) – Covers reliability fundamentals, system modeling, maintainability and availability (onlinecourses.nptel.ac.in) Introduction to Reliability Engineering - Course
2. Patrick D T O'Connor, Andre Kleyner, "Practical Reliability Engineering", John-Wiley and Sons Inc, 5th edition ,2015. .
3. Dhillon, "Engineering Maintainability – How to design for reliability and easy maintenance", PHI,2008.

26MEE106

INDUSTRIAL ROBOTICS AND ARTIFICIAL INTELLIGENCE

(Programme Elective– II)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:

This course aims to cover:

1. The fundamental concepts of robot kinematics, dynamics, and trajectory planning.
2. The core principles of artificial intelligence and machine learning as applicable to industrial automation.
3. The integration of computer vision, sensing systems, and logic building for autonomous decision-making.
4. The deployment of robotics and AI in advanced manufacturing systems and non-conventional machining.
5. The approaches to data analysis, predictive maintenance, and intelligent fault diagnosis in robotic workcells.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Formulate direct and inverse kinematics, and analyze workspace configurations using linear algebra concepts.
2. Design and control robotic manipulators for specific industrial trajectories.
3. Implement machine learning algorithms and computer vision techniques for robotic perception and guided tasks.
4. Apply intelligent automation to advanced manufacturing processes, including electrochemical and electrical discharge machining.
5. Develop predictive maintenance and condition monitoring pipelines using modern programming environments.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	3	2	2
CO2	3	3	2	2
CO3	3	3	3	2
CO4	3	3	2	2
CO5	3	3	3	2

UNIT - I

INTRODUCTION TO ROBOTICS AND KINEMATICS

Fundamentals of Robotics: History, classification, and anatomy of industrial robots. Robot specifications (payload, reach, accuracy, repeatability).

Spatial Transformations: Translation, rotation, and homogeneous transformation matrices. Application of linear algebra (matrix rank and nullity) in analyzing robotic workspace and singular configurations.

Kinematics: Forward and inverse kinematics. Denavit-Hartenberg (D-H) convention. Forward and inverse kinematics of standard industrial manipulators (SCARA, PUMA).

UNIT- II

ROBOT DYNAMICS AND CONTROL

Manipulator Dynamics**:** Formulation of dynamic equations of motion. Lagrange-Euler and Newton-Euler formulations.

Trajectory Planning: Joint-space and Cartesian-space trajectory generation. Cubic polynomials and linear functions with parabolic blends.

Control Systems: Architecture of robotic control systems. Independent joint control, PID control, computed torque control, and force/impedance control strategies for manufacturing tasks.

UNIT- III

ARTIFICIAL INTELLIGENCE IN AUTOMATION

Introduction to AI and ML: Role of Artificial Intelligence in Industry 4.0. Logic building and decision-making frameworks for autonomous systems.

Machine Learning Paradigms: Supervised learning, unsupervised learning, and reinforcement learning for robot control and dynamic path planning.

UNIT - IV

MACHINE VISION AND SENSORY SYSTEMS

Robotic Sensors: Internal and external sensors. Position, velocity, force/torque, tactile, and advanced proximity sensing.

Computer Vision Fundamentals: Image acquisition, digitization, and preprocessing. Techniques for image enhancement, thresholding, and background removal in dynamic industrial settings. Feature extraction and object recognition.

Vision Integration: Vision-guided robotics (VGR), visual servoing, and depth estimation. Safe human-machine interaction leveraging intelligent sensory arrays .

UNIT - V

INTELLIGENT MANUFACTURING AND PROACTIVE MAINTENANCE

AI in Advanced Manufacturing: Robotic applications in complex manufacturing processes, including welding, precision assembly, and non-conventional machining (Electrical Discharge Machining, Electrochemical Machining, and Ultrasonic Machining).

Smart Workcells: Integration of cyber-physical systems, smart factories, and digital twins for robotic cell simulation.

Text Books:

1. Craig, J. J., "Introduction to Robotics: Mechanics and Control", Pearson Education, 4th Edition, 2017.
2. Russell, S. and Norvig, P., "Artificial Intelligence: A Modern Approach", Pearson, 4th Edition, 2020.
3. Groover, M. P., "Industrial Robotics: Technology, Programming, and Applications", McGraw Hill, 2nd Edition, 2012.
4. Siegwart, R., Nourbakhsh, I. R., and Scaramuzza, D., "Introduction to Autonomous Mobile Robots", MIT Press, 2nd Edition, .

Suggested Reading:

1. Niku, S. B., "Introduction to Robotics: Analysis, Control, Applications", Wiley, 3rd Edition, 2020.
2. Goodfellow, I., Bengio, Y., and Courville, A., "Deep Learning", MIT Press, 2016.
3. Siciliano, B., and Khatib, O. (Eds.), "Springer Handbook of Robotics", Springer, 2nd Edition, 2016.

26MEM101

RESEARCH METHODOLOGY AND IPR

Instruction	2 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	2

Course Objectives:

To make the students to

1. Motivate to choose research as career
2. Formulate the research problem, prepare the research design
3. Identify various sources for literature review and data collection report writing
4. Equip with good methods to analyze the collected data
5. Know about IPR copyrights

Course Outcomes:

Upon completion of this course, students will be able to:

1. Define research problem, review and asses the quality of literature from various sources
2. Improve the style and format of writing a report for technical paper/ Journal report, understand and develop various research designs.
3. Collect the data by various methods: observation, interview, questionnaires.
4. Analyze problem by statistical techniques: ANOVA, F-test, and Chi-square.
5. Understand apply for patent and copyrights.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	2	1	2
CO2	3	3	3	2
CO3	3	2	2	1
CO4	3	1	2	2
CO5	3	3	3	3

UNIT - I

Research Methodology: Research Methodology: Objectives and Motivation of Research, Types of Research, research approaches, Significance of Research, Research Methods verses Methodology, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India, Benefits to the society in general. Defining the Research Problem: Selection of Research Problem, Necessity of Defining the Problem.

UNIT - II

Literature Survey Report writing: Literature Survey: Importance and purpose of Literature Survey, Sources of Information, Assessment of Quality of Journals and Articles, Information through Internet. Report writing: Meaning of interpretation, layout of research report, Types of reports, Mechanics of writing a report. Research Proposal Preparation: Writing a Research Proposal and Research Report, Writing Research Grant Proposal. Introduction to latex ,Basic rules, LaTeX templates — Reports.

UNIT- III

Research Design: Research Design: Meaning of Research Design, Need of Research Design, Feature of a Good Design, Important Concepts Related to Research Design, Different Research Designs, Basic Principles of Experimental Design, Developing a Research Plan, Steps in sample design, types of sample designs.

UNIT - IV

Data Collection and Analysis: Data Collection: Methods of data collection, importance of Parametric, non parametric test, testing of variance of two normalpopulation, use of Chi-square, ANOVA, Ftest, z-test.

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UNIT - V

Patents and Copyright: Patent: Macro economic impact of the patent system,Patent document, How to protect your inventions. Granting of patent, Rights of a patent, how extensive is patent protection. Copyright: What is copyright. What is covered by copyright? How long does copyright last? Why protect copyright? Related Rights: what are related rights? Enforcement of IntellectualProperty Rights: Infringement of intellectual property rights, Case studies of patents and IP Protection.

Text Books:

1. C.R Kothari, "Research Methodology, Methods & Technique"; New Age International Publishers, 2004
2. R. Ganesan, "Research Methodology for Engineers", MJP Publishers , 2011
3. Y.P. Agarwal, "Statistical Methods: Concepts, Application and Computation", Sterling Publs., Pvt., Ltd., New Delhi, 2004.

Suggested Reading:

1. Ajit Parulekar and Sarita D' Souza, "Indian Patents Law – Legal & Business Implications"; Macmillan India ltd , 2006
2. B. L.Wadehra; "Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications"; Universal law Publishing Pvt. Ltd., India2000.
3. P. Narayanan; "Law of Copyright and Industrial Designs"; Eastern law House, Delhi 2010.

26CEA101

DISASTER MITIGATION AND MANAGEMENT
(Audit Course I and II - Common to all branches)

Instruction	2 L Hours per Week
Duration of SEE	2 Hours
SEE	50 Marks
CIE	0 Marks
Credits	Pass/Fail

Course Objectives:

To enable the students to

1. To equip the students with the basic knowledge of hazards, disasters, risks and vulnerabilities, including natural, climatic and human-induced factors and associated impacts
2. To impart knowledge in students about the nature, causes, consequences and mitigation measures of the various natural disasters
3. To enable the students to understand risks, vulnerabilities and human errors associated with human-induced disasters
4. To enable the students to understand and assimilate the impacts of any disaster on the affected area, depending on its position/ location, environmental conditions, demographic, etc
5. To equip the students with the knowledge of the chronological phases in a disaster management cycle and to create awareness about the disaster management framework and legislations in the context of national and global conventions.

Course Outcomes:

At the end of the course, students will be able to

1. Ability to analyse and critically examine existing programs in disaster management regarding vulnerability, risk and capacity at different levels
2. Ability to understand and choose the appropriate activities and tools, and set up priorities to build a coherent and adapted disaster management plan
3. Ability to understand various mechanisms and consequences of human-induced disasters for the participatory role of engineers in disaster management
4. To understand the impact on various elements affected by the disaster and to suggest and apply appropriate measures for the same
5. Develop an awareness of the chronological phases of disaster preparedness, response and relief operations for formulating effective disaster management plans and the ability to understand various participatory approaches/strategies and their application in disaster management

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO1	2	3	2	2
CO2	3	3	2	2
CO3	2	3	3	2
CO4	3	3	2	2
CO5	3	2	2	2

UNIT- I:

Introduction: Basic definitions- Hazard, Disaster, Vulnerability, Risk, Resilience, Mitigation, Management; classification of types of disaster-Natural and manmade; International Decade for natural disaster reduction (IDNDR); International strategy for disaster reduction (ISDR), National disaster management authority (NDMA).

UNIT- II:

Natural Disasters: Hydro meteorological disasters: Causes, Early warning systems- monitoring and management, structural and non-structural measures for floods, drought and Tropical cyclones; Geographical based disasters: Tsunami generation, causes, zoning, Early warning systems- monitoring and management, structural and non-structural mitigation measures for earthquakes, tsunami, landslides, avalanches and forest fires. Case studies related to various hydro-meteorological and geographical based disasters.

UNIT- III:

Human induced hazards: Chemical disaster- Causes, impacts and mitigation measures for chemical accidents, Risks and control measures in a chemical industry, chemical disaster management; Case studies related to various chemical industrial hazards eg.: Bhopal gas tragedy; Management of chemical terrorism disasters and biological disasters; Radiological Emergencies and case studies; Case studies related to major power break downs, fire accidents, traffic accidents, oil spills and stampedes, disasters due to double cellar construction in multistoried buildings.

UNIT- IV:

Disaster Impacts: Disaster impacts- environmental, physical, social, ecological, economic, political, etc.; health, psycho-social issues; demographic aspects- gender, age, special needs; hazard locations; global and national disaster trends; climate change and urban disasters.

UNIT- V:

Concept of Disaster Policies and legislation for disaster risk reduction

Management: Disaster management cycle – its phases; prevention, mitigation, preparedness, relief and recovery; risk analysis, vulnerability and capacity assessment; post-disaster environmental response water, sanitation, food safety, waste management, disease control; Roles and responsibilities of government, community, local in situations, NGOs and other stakeholders;, DRR programmers in India and the activities of National Disaster Management Authority.

Text Books:

1. Pradeep Sahni*," Disaster Risk Reduction in South Asia*", Prentice Hall, 2003.
2. B. K. Singh,*" Handbook of Disaster Management*: *techniques &Guidelines*", Rajat Publication, 2008.
3. Ministry of Home Affairs". *Government of India, "National disaster management plan, Part I and II",*
4. K. K. Ghosh," *Disaster Management",* APH Publishing Corporation, 2006.

Suggested Reading:

1. http://www.indiaenvironmentportal.org.in/files/file/disaster_management_india1.pdf
2. http://www.ndmindia.nic.in/ (National Disaster management in India, Ministry of Home Affairs)
3. Hazards, Disasters and your community: A booklet for students and the community, Ministry of home affairs.

26EEA101

SANSKRIT FOR COMPUTATIONAL THINKING & ENGINEERING APPLICATIONS

(Common to All Branches)

Instruction	2 L Hours per Week
Duration of SEE	2 Hours
SEE	50 Marks
CIE	--
Credits	0

Course Objectives: This course aims to

1. Introduce Sanskrit as a structured language useful for logical thinking and algorithm design
2. Connect Sanskrit concepts with modern engineering domains (AI, circuits, structures, systems)
3. Develop computational and analytical skills using Sanskrit-based principles
4. Enable students to explore interdisciplinary applications for research and innovation

Course Outcomes: After completion, students will be able to:

1. Apply structured Sanskrit rules to improve logical and algorithmic thinking
2. Relate concepts from Sanskrit texts to modern Engineering principles
3. Develop simple computational models inspired by Sanskrit grammar/logics
4. Use Sanskrit-based frameworks in AI, coding logic, or system design
5. Identify interdisciplinary research opportunities combining Sanskrit & Engineering

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	1	2	2
CO2	2	2	2	3
CO3	3	2	2	3
CO4	3	2	2	3
CO5	3	2	2	3

UNIT-I

Sanskrit as rule-based system -Basics: alphabets, word formation (only essentials) -Sandhi as **data compression analogy** -Samasa as **modular design / block abstraction**-Simple sentence formation (very minimal grammar)

UNIT-II

Sanskrit & Computational Thinking

Paninian grammar → rule engine / compiler design -Shiva Sutras → encoding system-Binary concepts in Pingala (Chandas → digital logic) -Recursion & patterns in Sanskrit structures

UNIT-III

Sanskrit in Core Engineering Domains

Civil / Mechanical:

Sulba Sutras → geometry, measurements -Ancient construction logic → modular design

Electrical / ECE:

Concept of energy (Agni, Surya) → symbolic + physical mapping -Wave & sound (Nada → signal analogy)

Systems Thinking: Interconnectedness → system design philosophy

UNIT-IV
Sanskrit & Modern Technology
Sanskrit & Artificial Intelligence (knowledge representation) -Natural Language Processing (NLP) -Formal languages & syntax -Command-based structures → programming analogy

UNIT-V
Mini Applications & Case Studies
Case study: Sanskrit → Algorithm (simple flowchart) -Chandas → binary pattern generation-Design a simple rule-based system using Sanskrit logic -Mini presentation / activity

Text Books:

1. Kapil Kapoor – Language, Linguistics and Literature- Indian Perspective ; Academic Foundation, New Delhi; 1994 (1st Edition); ISBN: 978-8171880577
2. Frits Staal : *A Reader on the Sanskrit Grammarians;* MIT Press / Motilal Banarsidass ; 1972 (Original); ISBN: 978-0262191340
3. George Gheverghese Joseph: The Crest of the Peacock"; Princeton University Press; 2000 (2nd Edition; widely used); ISBN: 978-0691135267
4. B.V. Subbarayappa: "Indian Scientific Heritage" – National Institute of Advanced Studies (NIAS), Bangalore; 2006 ISBN: 978-8185015026
5. – M. Krishnamachariar : "History of Sanskrit Literature"; Motilal Banarsidass Publishers; Reprint 1993 (Original: 1937, TTD Press); ISBN: 978-8120802841

Suggested Reading:

1. Pingala. *Chandah Shastra* (various editions, Nirnaya Sagar Press / Chowkhamba)
2. Bharati, A., et al. *Natural Language Processing: A Paninian Perspective*, PHI, 1995
3. Selected IEEE / Springer Papers on Sanskrit & AI

26ECA101

VALUE EDUCATION

Instruction	2 L Hours per Week
Duration of SEE	2 Hours
SEE	50 Marks
CIE	--
Credits	Non-Credit

Prerequisite:

COURSE OBJECTIVES: This course aims to

1. Understand Value Education, Self-development and National development.
2. Imbibe good human values and Morals in students.
3. Cultivate individual and National character.

COURSE OUTCOMES: After the completion of this course, the student will be able to

1. Summarize classification of values and values for self-development.
2. Identify the importance of values in personal and professional life.
3. Apply the importance of social values for better career and relationships.
4. Analyze ethical issues in modern technology
5. Discuss concept of soul and reincarnation and promote responsible citizenship

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	1	1	2	2
CO 2	1	2	2	2
CO 3	2	2	2	3
CO 4	2	2	3	3
CO 5	1	2	2	3

UNIT-I

Human Values, Ethics and Morals: Concept of Values, Human Values, Indian concept of humanism, Values for self-development, Social values, Individual attitudes, Work ethics, Moral and non- moral behavior, Standards and Principles based on religion, Culture and Tradition**.**

UNIT-II

Value Cultivation, and Self-Management: Need and Importance of cultivation of values such as Sense-of Duty, Devotion to work, Self-reliance, Confidence, Concentration, Integrity & discipline, and Truthfulness.

UNIT-III

Spiritual Outlook and Social Values: Personality and Behaviour Development, Scientific attitude and Spiritual (soul) outlook, Cultivation of Social Values Such as Positive Thinking, Punctuality, Love & Kindness, Avoiding fault finding in others, Reduction of anger, Forgiveness, Dignity of labour, True friendship, Universal brotherhood and religious tolerance., Happiness Vs Suffering, Love for truth, Aware of self-destructive habits, Appreciation and co-operation.

UNIT-IV

Technology, Society, and Sustainability: Ethics in emerging technologies (AI, Data, 5G, IoT); Privacy and cybersecurity, Environmental ethics and sustainable development; Social responsibility of engineers, Policy and governance.

UNIT-V

Universal Values and Global Perspectives: Mind your mind, Self-control**,** Concept of soul, Science of Reincarnation, Concepts of Dharma and Karma, The qualities of Devine and Devilish, Satwic, Rajasic and

Tamasicgunas. Global citizenship, Happiness and meaningful life.

Text Book:

1. Chakroborty, S.K. “Values & Ethics for organizations Theory and practice”, Oxford University Press, New Delhi, 1998.
2. Jaya Dayal Goyandaka, “Srimad Bhagavad Gita”, with Sanskrit Text, Word meaning and Prose meaning, Gita Press, Gorakhpur, 2017

Suggested Reading:

1. George Reynolds, Ethics in Information Technology, 6th Edition, Cengage Learning, 2018
2. Melanie Mitchell, Artificial Intelligence: A Guide for Thinking Humans, 1st Edition, Farrar, Straus and Giroux, 2019

26ADA101

PEDAGOGY STUDIES

Instruction	2 Hours per week
Duration of SEE	2 Hours
SEE	50 Marks
CIE	-
Credits	0

Course Objectives:

1. To present the basic concepts of design and policies of pedagogy studies.
2. To provide understanding of the abilities and dispositions with regard to teaching techniques, curriculum design and assessment practices.
3. To familiarize various theories of learning and their connection to teaching practice.
4. To create awareness about the practices followed by DFID, other agencies and other researchers.
5. To provide understanding of critical evidence gaps that guides the professional development.

Course Outcomes:

Upon completing this course, students will be able to:

1. Illustrate the pedagogical practices followed by teachers in developing countries both in formal and informal classrooms.
2. Examine the effectiveness of pedagogical practices.
3. Understand the concept, characteristics and types of educational research and perspectives of research.
4. Describe the role of classroom practices, curriculum and barriers to learning.
5. Understand Research gaps and learn the future directions

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	1	1	1	-
CO2	1	1	1	-
CO3	2	2	2	-
CO4	1	1	1	-
CO5	2	2	2	-

UNIT I

Introduction and Methodology: Aims and rationale, Policy background, Conceptual framework and terminology - Theories of learning, Curriculum, Teacher education - Conceptual framework, Research questions - Overview of methodology and searching.

UNIT II

Thematic Overview: Pedagogical practices followed by teachers in formal and informal classrooms in developing countries - Curriculum, Teacher education.

UNIT III

Evidence on the Effectiveness of Pedagogical Practices: Methodology for the in depth stage: quality assessment of included studies - How can teacher education (curriculum and Practicum) and the school curriculum and guidance material best support effective pedagogy? - Theory of change - Strength and nature of the body of evidence for effective pedagogical practices - Pedagogic theory and pedagogical approaches - Teachers' attitudes and beliefs and pedagogic strategies.

UNIT IV

Professional Development: alignment with classroom practices and follow up support - Support from the head

teacher and the community – Curriculum and assessment - Barriers to learning: Limited resources and large class sizes.

UNIT-V

Research Gaps and Future Directions: Research design – Contexts – Pedagogy - Teacher education - Curriculum and assessment – Dissemination and research impact.

Text Books:

1. Ackers J, Hardman F, "Classroom Interaction in Kenyan PrimarySchools, Compare", 31 (2): 245 – 261, 2001.
2. Agarwal M, "Curricular Reform in Schools: The importance of evaluation", Journal of Curriculum Studies, 36 (3): 361 – 379, 2004.

26EGA101

ENGLISH FOR RESEARCH PAPER WRITING

(M.E/M. Tech - Common to all Branches)

Instruction	2 L Hours per Week
Duration of SEE	2 Hours
SEE	50 Marks
CIE	-
Credits	0

Prerequisite: Writing to express on science and technological concepts with good taste for research and development.

Course Objectives:

This course aims to:

1. Motivate learners for academic writing and thus encourage them for continuous professional updating and up-gradation.
2. Facilitate a practical understanding of the multiple purposes of Writing Research Papers and help them infer the benefits and limitations of research in science and technology.
3. Brainstorm and develop the content, formulating a structure and illustrating the format of writing a research paper.
4. Survey and select a theme/topic for a thorough reading and to writing a research paper.
5. Understand to implement the intricacies of writing and publishing a research paper.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Improve work performance and efficiency. Illustrate the nuances of research paper writing and draw conclusions on professional usefulness.
2. Classify different types of research papers and organize the format and citation of sources.
3. Explore various formats of APA, MLA and IEEE and set up for writing a research paper.
4. Draft paragraphs and write theme based thesis statements in a scientific manner.
5. Develop an original research paper while acquiring the knowledge of how and where to publish their papers.

CO-PO Articulation Matrix

PO/PSO / CO	PO1	PO2	PO3	PO4
CO 1	1	2	1	1
CO 2	1	1	1	-
CO 3	2	2	2	-
CO 4	2	2	1	1
CO 5	3	3	1	2

UNIT - I

Academic Writing: Meaning & Definition of a research paper; Purpose of a research paper - Scope, Benefits, Limitations and outcomes for professional development, An introduction to methods and Approaches of Research.

UNIT - II

Research Paper Format: Title - Abstract - Introduction - Discussion - Findings - Conclusion - Style of Indentation - Font size/Font types - Indexing - Citation of sources.

UNIT - III

Process of Writing a research paper, Writing to Draft a Format, Develop content, Adapting, Reviewing, Para-

phrasing& Plagiarism Checks.

UNIT - IV

Choosing a topic - Thesis Statement - Outline - Organizing notes - Language of Research - Word order, Paragraphs - Writing first draft-Revising/Editing - The final draft and proof reading. Understanding APA, MLA, IEEE formats.

UNIT - V

Research Paper Publication Reputed Journals –Paid, Free and peer reviewed journals, National/International - ISSN No, No. of volumes, Scopus Index/UGC Journals. Getting Papers Published.

Text Books:

1. Kothari, C. R. and Gaurav, Garg, Research Methodology Methods and Techniques", 4thEdition, New Age International Publishers, New Delhi, 2019.
2. Ellison, Carroll. "Writing Research Papers", McGraw Hill's Concise Guide, 2010.
3. Lipson, Charles. "Cite Right: A Quick Guide to Citation Styles-- MLA, APA, Chicago, the Sciences, Professions, and More", 2nd Edition,. University of Chicago Press. Chicago, 2018.

Suggested Reading:

1. Day, Robert A. "How to Write and Publish a Scientific Paper", Cambridge University Press, 2006
2. Girden, E. R. "MLA Hand book for writers of Research Papers", 7th Edition, East West Press Pvt. Ltd, New Delhi, 2009
3. Bailey, Stephen. "Academic Writing: A Handbook for International Students", Routledge, 2018

Online Resources:

1. https://onlin://onlinecourses.nptel.ac.in/noc 18_mg13/preview
2. https://nptel.ac.in/courses/121/106/121106007/
3. https://www.classcentral.com/course/swayam-introduction-to-research-5221

Writing Tools:

1. https://owl.purdue.edu/owl_exercises/index.html - The Owl writing lab
2. https://www.turnitin.com/login_page.asp?lang=en_us – Turn tin software

26EGA102

CONSTITUTION OF INDIA
(M.E/M. Tech - Common to all Branches)

Instruction	2 L Hours per Week
Duration of SEE	2 Hours
SEE	50 Marks
CIE	-
Credits	0

Course Objectives:
This course aims to
1. The history of Indian Constitution and its role in the Indian democracy.
2. Get awareness on Fundamental Rights, Duties and Directive Principles of State Policy.
3. Understand the structure and organization of Union Executive, Legislature and Judiciary.
4. Examine the powers and functions of Election Commission and State Election Commission
5. Explore the decentralization of administration in India through Local bodies.

Course Outcomes:
Upon completion of this course, students will be able to:
1. Understand the making of the Indian Constitution and its features.
2. Establish relations among Directive Principles of State Policy, Fundamental Rights and Fundamental Duties.
3. Have an insight into various Organs of Governance at Union level.
4. Understand powers and functions of Urban local bodies and Panchayats.
5. Grasp the role of Election Commission and other organizations in safeguarding Constitution and protecting the rights of Citizens.

CO-PO Articulation Matrix

PO/PSO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	1	1	-	1
CO 2	1	1	-	1
CO 3	1	1	-	1
CO 4	1	1	-	1
CO 5	-	-	-	1

UNIT-I

History of making of the Indian constitutions - History, Drafting Committee (Composition & Working). Philosophy of the Indian Constitution: Preamble, Salient Features.

UNIT-II

Contours of Constitutional Rights and Duties - Fundamental Rights: Significance of Rights. Directive Principles of State Policy: Relevance and Importance. Fundamental Duties: Importance of Duties.

UNIT-III

Organs of Governance – Union Legislature: Parliament-Composition, Qualifications, Powers and Functions. Union executive: President, Prime Minister and Council of Ministers. Judiciary: appointment and transfer of judges, qualifications, powers and functions.

UNIT-IV

Local Administration - District's Administration head: Role and Importance. Municipalities: Structure and Functions, Municipal Corporation: Mayor and Role of Commissioner. Panchayati Raj: Zilla Panchayat, Elected Officials and their roles, CEO: Position and Role. Block level: Organizational Hierarchy. Village level: Role of

elected and appointed officials. Importance of grass roots democracy.

UNIT-V

Election commission: Election Commission: Role and functioning, Chief Election Commissioner and Election Commissioners. State Election Commission: Role and functioning. Institutes and Bodies for the welfare of SC/ST/OBC and Women.

Text Books:

1. The Constitution of India, 1950 (Bare Act), Government Publication.
2. Busi, S. N., Dr. B. R. Ambedkar, Framing of Indian Constitution'', 1st Edition, Ava Publishers, New Delhi, 2015.
3. Jain, M. P., "Indian Constitution Law", 7th Edition, Lexis Nexis, New Delhi, 2014.
4. Basu, D.D. "Introduction to the Constitution of India", Lexis Nexis, New Delhi., 2015

Suggested Reading:

1. Bhargava, Rajeev. (ed), "Politics and Ethics of the Indian Constitution", OUP, 2008.
2. NCERT, Indian Constitution at Work, 1st Edition, Government of India, New Delhi 2006, reprinted in 2022.
3. Ravindra Sastry, V. (ed.), Indian Government & Politics, 2nd edition, Telugu Akademy, 2018.

Online Resources:

1. http://www.nptel.ac.in/courses/103107084/Script.pdf

26EGA103

STRESS MANAGEMENT BY YOGA

(M.E/M. Tech - Common to all Branches)

Instruction	2 L Hours per Week
Duration of SEE	2 Hours
SEE	50 Marks
CIE	-
Credits	0

Prerequisite: Knowledge on Yoga Practices.

Course Objectives:

This course aims to:

1. Create awareness about different types of stress and the role of yoga in the management of stress.
2. Promote positive health and overall well-being (Physical, mental, emotional, social and spiritual).
3. Prevent stress related health problems by yoga practice.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand yoga and its benefits.
2. Enhance Physical strength and flexibility.
3. Learn to relax and focus.
4. Relieve physical and mental tension through asanas
5. Improve work performance and efficiency

CO-PO Articulation Matrix

PO/PSO / CO	PO1	PO2	PO3	PO 4
CO 1	1	1	-	-
CO 2	1	-	-	-
CO 3	1	-	-	1
CO 4	1	1	-	-
CO 5	1	1	-	1

UNIT - I

Meaning and definition of Yoga - Historical perspective of Yoga - Principles of Astanga Yoga by Patanjali).

UNIT - II

Meaning and definition of Stress - Types of stress - Eustress and Distress. Anticipatory Anxiety and Intense Anxiety and depression. Meaning of Management- Stress Management.

UNIT - III

Concept of Stress according to Yoga - Stress assessment methods - Role of Asana, Pranayama and Meditation in the management of stress.

UNIT - IV

Asanas- (5 Asanas in each posture) - Warm up - Standing Asanas - Sitting Asanas - Prone Asanas - Supine asanas - Surya Namaskar

UNIT – V

Pranayama- Anulom and Vilom Pranayama - Nadishudhi Pranayama - Kapalabhati Pranayama - Bhramari Pranayama - Nadanusandhana Pranayama.

Meditation techniques: Om Meditation - Cyclic meditation: Instant Relaxation technique (QRT), Quick Relaxation Technique (QRT), Deep Relaxation Technique (DRT)

Text Books:

1. Janardhan, Swami, "Yogic Asanas for Group Training - Part-I": Yogabhyasi Mandal, Nagpur.
2. Vivikananda, Swami**.** "Rajayoga or Conquering the Internal Nature", Advaita Ashrama (Publication Department), Kolkata.
3. Nagendra H.R and R. Nagaratna, "Yoga Perspective in Stress Management", Swami Vivekananda Yoga Prakashan, Bangalore.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc16_ge04/preview

26EGA104

PERSONALITY DEVELOPMENT THROUGH LIFE'S ENLIGHTENMENT SKILLS

(M.E/M. Tech - Common to all Branches)

Instruction	2 L Hours per Week
Duration of SEE	2 Hours
SEE	50 Marks
CIE	-
Credits	0

Course Objectives:

This course aims to:

1. Learn to achieve the highest goal happily.
2. Become a person with stable mind, pleasing personality and determination.
3. Awake wisdom among themselves.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Develop their personality and achieve their highest goal of life.
2. Lead the nation and mankind to peace and prosperity.
3. Practice emotional self-regulation.
4. Develop a positive approach to work and duties.
5. Develop a versatile personality.

CO-PO Articulation Matrix

PO/PSO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	1	1	-	1
CO 2	1	-	-	1
CO 3	1	-	-	-
CO 4	1	1	-	1
CO 5	1	1	-	1

UNIT - I

Neetisatakam – Holistic development of personality - Verses 19, 20, 21, 22 (Wisdom) - Verses 29, 31, 32 (Pride and Heroism) - Verses 26,28,63,65 (Virtue)

UNIT - II

Neetisatakam – Holistic development of personality (cont'd) - Verses 52, 53, 59 (dont's) - Verses 71,73,75& 78 (do's) - Approach to day to day works and duties.

UNIT - III

Introduction to Bhagavadgeetha for Personality Development – Shrimad Bhagawad Geeta: Chapter 2– Verses 41, 47, 48 - Chapter 3 – Verses 13,21,27,35 - Chapter 6 – Verses 5,13,17,23,35 - Chapter 18 – Verses 45, 46, 48 Chapter – 6: Verses 5, 13, 17, 23, 35; Chapter – 18: Verses 45, 46, 48

UNIT - IV

Statements of basic knowledge – Shrimad Bhagawad Geeta: Chapter 2- Verses 56, 62,68 - Chapter 12 – Verses 13, 14, 15, 16, 17, 18 - Personality of Role model from Shrimad Bhagawat Geeta.

UNIT - V

Role of Bahgavadgeeta in the present scenario - Chapter 2 – Verses 17 - Chapter 3 – Verses 36, 37, 42 - Chapter 4 – Verses 18, 38, 39 - Chapter 18 – Verses 37, 38, 63.

Suggested Readings:

1. Gopinath, P., "Bhartrihari's Three Satakam (Niti-sringar-vairagya)", Rashtriya Sanskrit Sansthanam, New Delhi, 2018.
2. Swarupananda, Swami, "Srimad Bhagavad Geeta", Advaita Ashram (Publication Dept), Kolkata, 2017.

Online Courses:

1. http://nptel.ac.in/downloads/109104115/

26MEC103

ADVANCED COMPUTER AIDED DESIGN LAB

Instruction	2 L Hours per Week
Duration of SEE	-
SEE	-
CIE	50 Marks
Credits	1

COURSE OBJECTIVES: This course aims to

1. introduce fundamentals of engineering drawing and 3D CAD modeling techniques.
2. enable students to create 3D parts using standard modeling features.
3. develop skills in assembly modeling with proper constraints and motion understanding.
4. provide knowledge of GD&T and preparation of Bill of Materials for engineering designs.
5. train students in surface modeling and preparation of CAD models for engineering analysis applications.

COURSE OUTCOMES: After successful completion of the course the students will be able to

1. Model 3D parts using standard CAD features such as extrude, revolve, loft, sweep, fillet, and chamfer
2. Develop and assemble mechanical components with proper constraints and mass property evaluation.
3. Apply GD&T and generate Bill of Materials (BOM) for engineering assemblies.
4. Create surface models of complex engineering components
5. Prepare CAD models for simulation and analysis applications

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	1	2	1
CO2	2	2	3	1
CO3	2	2	3	2
CO4	2	2	3	1
CO5	2	2	3	3

List of Experiments:

1. Introduction to concepts of machine drawing and production drawing.
2. Part modelling of a components using Extrude Boss, Extrude Cut, Fillet, Chamfer with mass properties
3. Part modelling of a components using Revolve, Rib with mass properties
4. Part modeling of a components using loft, sweep with mass properties
5. Assembly modeling of stuffing box components with mass properties
6. Assembly modeling of screw jack components with mass properties
7. Assembly modeling of Flange coupling with mass properties
8. Modeling of I.C engine connecting rod with GD&T, Bill of materials
9. Modeling of square tool post or single tool post with GD&T, Bill of materials
10. Modeling of revolve center with GD&T, Bill of materials
11. Surface modeling of automobile outer surface
12. Study of CAD model preparation of an aerofoil for CFD analysis.

Note: Out of the above 12 experiments, any 10 experiments must be carried out.

Suggested Reading :

1. Solidworks Essentials, “Solidworks” By Dassault Systems

26MEC104

DIGITAL MANUFACTURING LAB

Instruction	2 L Hours per Week
Duration of SEE	-
SEE	-
CIE	50 Marks
Credits	1

Course Objectives:

This course aims to

1. Introduce to the students the additive manufacturing machines
2. Impart knowledge about various materials used for the digital fabrication
3. Demonstrate rapid tooling concept
4. Demonstrate reverse engineering process
5. Impart knowledge about tool path generation

Course Outcomes:

Upon completion of this course, students will be able to:

1. Compare different Additive and subtractive manufacturing process and select a process for a particular application
2. Perform preprocessing and post processing for 3D printing.
3. Create 3D model by reverse Engineering.
4. Generate tool path data for a given component
5. Perform DFA analysis for a simple assembly.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	1	2	-
CO2	2	-	2	-
CO3	1	-	2	-
CO4	3	-	2	-
CO5	2	1	2	1

List of the Experiments

1. Introduction to CNC part programming and machining.
2. Pocket Milling operations using CNC Machine
3. Step turning operation using CNC Lathe
4. Taper Turning operation using CNC Lathe
5. Introduction to RP machine, Machine Specifications, Materials, Stl file generation & Slicing.
6. 3D printing of Stuffing Box
7. To perform the post processing operations
8. Manufacturing of a water bottle die
9. Demonstration of 3D printing of a component using Resin based printer.
10. Reverse engineering: From 3D scanner to model validation (solid works).
11. Part program for the generation of Crane Hook using CAM software
12. Perform DFMEA analysis for a simple assembly.

Note: Out of the above 12 experiments, any 10 experiments can be carried out.

Text Books:

1. Gibson, DW. Rosen and B.Stucker; "Additive manufacturing methodologies: Rapid prototyping to direct digital manufacturing ", Springer, 2010.
2. Product Design for Manufacture and Assembly, Geoffrey Boothroyd, Peter Dewhurst, Winston Knight, 2nd Edition, Marcel Dekker, New York.

26MEC105

VIBRATIONS AND CONDITION MONITORING LAB

Instruction	2 L Hours per Week
Duration of SEE	-
SEE	-
CIE	50 Marks
Credits	1

Course Objectives

1. To understand the fundamentals of vibration measurement and analysis.
2. To study free and forced vibration characteristics of mechanical systems.
3. To perform experimental modal analysis using accelerometers, impact hammer and DAQ system.
4. To analyze vibration signals in time and frequency domains using FFT techniques.
5. To develop practical knowledge on signal acquisition, filtering and condition monitoring methods.

Course Outcomes: After completion of the course, the student will be able to:

1. Measure and analyze vibration response of mechanical systems using accelerometers and DAQ systems.
2. Determine damping ratio, natural frequencies and mode shapes experimentally.
3. Perform forced vibration, transmissibility and resonance analysis using shaker excitation.
4. Apply FFT and signal processing techniques for vibration and fault analysis.
5. Acquire, filter and interpret vibration signals for machinery condition monitoring applications.

CO-PO Articulation Matrix

PO/PSO / CO	PO1	PO2	PO3	PO4
CO1	3	2	2	2
CO2	3	2	2	1
CO3	3	2	3	1
CO4	3	2	2	2
CO5	3	2	3	3

List of Experiments:

1) Measurement of free vibration response of a single degree of freedom system using accelerometer and DAQ system.
2) To determine the fundamental natural frequency of a cantilever beam using free vibration method and to estimate damping using logarithmic decrement. Also, to plot number of cycles versus damping.
3) To study the effect of adding a tip mass on a cantilever beam and determine the change in natural frequency and damping characteristics using free vibration response and logarithmic decrement method.
4) Forced vibration analysis of a structure under harmonic excitation using small shaker.
5) Frequency Response Function (FRF) measurement using impact hammer testing and DAQ system.
6) Experimental modal analysis of a cantilever beam using impact hammer and accelerometers.
7) Determination of natural frequencies and mode shapes of a simply supported beam.
8) Study of vibration transmissibility and resonance characteristics using shaker excitation.
9) FFT-based frequency spectrum analysis of vibration signals using DAQ system.
10) Measurement and comparison of RMS, peak value and crest factor of vibration signals.
11) Time domain and frequency domain analysis of vibration signals using accelerometers.
12) Orbit and phase analysis using multiple accelerometers mounted on rotating structure model.
13) Signal acquisition and filtering experiment using DAQ system, analog/digital filters and sampling.

NOTE: Student should complete 10 Experiments mandatory out of 13.

Suggested Text books:

1) C. Sujatha, Vibration, Acoustics and Strain Measurement: Theory and Experiments. Cham, Switzerland: Springer International Publishing, 2023.
2) Vibration Analysis, Instruments, and Signal Processing *by Jyoti Kumar Sinha was published by CRC Press in 2014.*
3) Mechanical Vibrations *by S. S. Rao was published by Pearson Education in 2017.*
4) Theory of Vibration with Applications by William T. Thomson and Marie Dillon Dahleh was published by Pearson in 2018.

Suggested Text books:

1) Fundamentals of Vibrations by Leonard Meirovitch was published by Waveland Press in 2010.
2) Noise and Vibration Analysis: Signal Analysis and Experimental Procedures by Anders Brandt was published by Wiley in 2011.

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CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY

R26 (In line with AICTE Model Curriculum) with effect from AY 2026-27

M.E. (CAD/CAM)

SEMESTER – II

S.no	Course Code	Title of the Course	Scheme of Instruction			Scheme of Examination			Credits
			Hours Per Week			Duration of SEE in Hours	Maximum Marks		
			L	T	P/D		CIE	SEE	
THEORY									
1	26MEC106	Finite Element Methods and Applications	3	--	--	3	40	60	3
2	26MEC107	Mechanical Design and Analysis	3	--	--	3	40	60	3
3	26MEC108	Manufacturing and Mechanics of Composite Materials	3	--	--	3	40	60	3
4		Program Elective - III	3	--	--	3	40	60	3
5		Program Elective - IV	3	--	--	3	40	60	3
PRACTICALS									
6	26MEC109	Computer Aided Engineering Lab	--	--	3	--	50	--	1.5
7	26MEC110	Mechanical Design and Analysis Laboratory	--	--	3	--	50	--	1.5
8	26MEC111	Mini Project with Seminar	--	--	2	--	50	--	1
Total			**15**	--	**8**	**15**	**350**	**300**	**19**
Clock Hours Per Week: 23									

L: Lecture **D: Drawing** **CIE: Continuous Internal Evaluation**

T: Tutorial **P: Practical/Project Seminar/Dissertation** **SEE: Semester End Examination**

Program Elective - III		Program Elective - IV	
26MEE107	Computational Methods in Engineering	26MEE110	Digital Twin and Industry 5.0
26MEE108	Advanced Optimization Techniques	26MEE111	Design for Manufacturing and Assembly
26MEE109	Fracture Mechanics	26MEE112	Machine Learning for Intelligent Systems

26MEC106

FINITE ELEMENT METHODS AND APPLICATIONS

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: To make the students to learn the
1. Fundamental understanding of the finite element method
2. stiffness matrix formulations for stepped bar
3. formulation of truss and beam problems
4. 2D structural problems using CST and axisymmetric elements
5. additional applications of FEM in the heat transfer and dynamics problems

Course Outcomes:
Upon completion of this course, students will be able to:
1. Apply FE method for solving field problems using virtual work and potential energy formulations
2. Analyze One-Dimensional stepped bar element
3. Solve and apply truss and beam element concepts to industrial applications
4. Analyze 2D structural problems using CST element and analyze axi-symmetric problems
5. Solve linear 1 D heat conduction and dynamic problems

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	1	2	3
CO2	3	1	3	3
CO3	3	1	3	3
CO4	3	1	3	3
CO5	3	1	3	3

UNIT – I
Introduction to Finite Element Method: General steps, advantages, and applications of the finite element method. Stress and equilibrium, boundary conditions, strain-displacement relations, stress-strain relations. Potential energy approach to derive spring element equations. Local, natural and global coordinate system

UNIT - II
One-Dimensional Element: Finite element formulation for 1-D (bar) element, coordinates and shape functions**,** derivation of stiffness matrix, properties of stiffness matrix, assembly of global stiffness matrix, treatment of boundary conditions, numerical problems on straight and stepped bars.(2 elements only)

UNIT- III
Trusses and Beams : Formulation plane trusses element, stiffness matrix, numerical problems on point load, formulation beam element, Numerical Problems on beams carrying concentrated, UDL and couples.(2 elements only)

UNIT- IV
Two Dimensional Element: Finite element modeling of two dimensional stress analysis problems with constant strain triangles and treatment of boundary conditions. Two dimensional four noded isoparametric elements and numerical integration. Finite element modeling of Axisymmentric solids subjected of axisymmetric loading with triangular elements.

UNIT- V

Additional Applications of FEM:

Heat Transfer Analysis: Steady state one dimensional heat conduction governing equation, numerical problem on composite wall, one dimensional heat transfer in fin

Dynamic Analysis: Formulation of finite element modeling of Eigen value problem for a stepped bar. Evaluation of Eigen values and Eigen vectors.

Text Books:

1. R. Tirupathi, Chandrupatla and A.D Ashok,"Introduction of Finite Element in Engineering", Prentice Hall of India, 2004
2. S.S. Rao,"The Finite Element Methods in Engineering", 2/e Pergamon Press, 2001.
3. David.V.Hutton, "Fundamentals of Finite Element Analysis", Tata McGrawHill,2003

Suggested Reading:

1. Robert Cook , "Concepts and applications of finite element analysis", 4/e, John Wiley andsons,2009
2. K..J Bathe,"Finite element procedures", 2/e,Prentice Hall of India,2007
3. D.L. Logan, "First course in finite element method", (5/e). Mason, OH: SouthWestern, Cengage Learning, 2011.

26MEC107

MECHANICAL DESIGN AND ANALYSIS

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Objectives: To make the students to

1. Develop the necessary skills to understand and analyze problems in pressure vessels.
2. Achieve fundamental understanding of the theory of bending offlatplates with various loading and boundary conditions
3. Understand design principles of a component and structures using fracture mechanics approaches.
4. Enable the importance of vibrations in mechanical design to understand the basic concepts of matrix algebra and understand thedifferent mode extraction methods in vibrations
5. Understand the fundamental concepts various algorithms used for dynamic analysis

Outcomes: At the end of the course, Student will be able to

1. Apply knowledge of mathematics, sciences and computations in solving the stresses & strains in pressure vessels
2. Demonstrate the ability to identify, formulate and solve problems for a given flat plate bending applications
3. Design a system or a component to meet the desired needs of fracturemechanics
4. Understand, solve various Eigen value and Eigen vectors and will understand different mode extraction methods to calculate frequencies
5. Understand methods in solving single degree freedom dynamicanalysis problems

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	2	2	1
CO2	3	2	2	1
CO3	2	2	3	2
CO4	3	2	3	1
CO5	3	2	2	1

UNIT - I

Design of Pressure Vessels: Introduction and selection of materials for pressure vessels, stresses in thick walled cylindrical pressure vessels subjected to both internal and external pressures, shrink fit stresses in built up cylinders, auto frettage of thick cylinders, thermal stresses and their significance.

UNIT - II

Stresses in Flat Plates: Introduction, Bending of plate in one direction, Bending of plate in two perpendicular directions, Thermal stresses in plates, Bending of circular plates of constant thickness, Bending of uniformly loaded plates of constant thickness

UNIT- III

Fracture Mechanics: Introduction, Modes of fracture failure Griffith Analysis, Energy release rate, Stress Intensity Factor: SIF‘s for edge and center line crack, Fracture toughness, Elastic plastic analysis through J-

integral method: Relevance and scope, Definition of J-integral, Path independence, Strain Energy Release Rate Vs J-integral.

UNIT - IV

Eigen Value Problems: Properties of Eigen values and Eigen Vectors, Torsional, Longitudinal vibration, lateral vibration, Sturm sequence method. Subspace iteration and Lanczo‘s method, Component mode synthesis.

UNIT - V

Dynamic Analysis: Direct integration method, Central difference method, Wilson- q method, Newmark method, Mode superposition, Single degree of freedom system response, Rayleigh damping. (Note: The related algorithms and codes to be practiced by students).

Text Books:

1. R. G. Budynas and J. K. Nisbett, *Shigley's Mechanical Engineering Design*, 12th ed. New York, NY, USA: McGraw-Hill Education, 2024.
2. John, V. Harvey, “Pressure Vessel Design: Nuclear and Chemical Applications”, Affiliated East West Press Pvt. Ltd., 1969.
3. Prasanth Kumar, “Elements of Fracture Mechanics”, Wheeler Publishing, NewDelhi-1999.
4. David.V .Hutton, “Fundamentals of Finite Element Analysis”, Tata McGraw Hill, 2003.

Suggested Reading:

1. G.Ramamurti, “Computer Aided Mechanical Design and Analysis”, Tata Mc Graw Hill-1992.
2. J. Bathe, “Finite Element Procedures”, Prentice Hall of India-1996.

26MEC108

MANUFACTURING AND MECHANICS OF COMPOSITE MATERIALS

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:
This course aims to

1. Provide the basics of composite materials, types of reinforcements, matrix materials and applications of composite materials.
2. Make the students understand the characterization of UD lamina/laminate using micro-mechanics approach and semi- empirical relations.
3. Provide understanding of the UD lamina using Macro-Mechanics approach.
4. Provide understanding on the analysis of laminates using Macro-Mechanics approach.
5. Familiarize the student with fabrication methods used composites.

Course Outcomes:
Upon completion of this course, students will be able to:

1. Understand the industrial need for composite materials, classification, application, advantages and disadvantages.
2. Apply micro mechanics to characterize the UD fiber reinforced composite materials.
3. Apply macro mechanics to characterize the lamina/laminate and theories of failure.
4. Analyze the laminates using CLT and failure mechanism.
5. Select a suitable manufacturing processes to develop fiber reinforced composite materials

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	1	3	1
CO2	3	1	3	1
CO3	3	1	3	1
CO4	3	1	3	1
CO5	3	1	3	1

UNIT - I

Introduction to Composite Materials: Fundamentals of Composites – Need for Composites – Enhancement of Properties – Classification of Composites – Matrix-Polymer Matrix Composites (PMC), Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC) – Reinforcement – Particle Reinforced Composites, Fibre Reinforced Composites. Applications of Various Types of Composites. Fibre Production Techniques for Glass, Carbon and Ceramic Fiber.

UNIT - II

Micromechanics of UD lamina and mechanical properties: Characterization of UD lamina, prediction of elastic moduli (E_1, E_2, G_{12} and υ_{12}) using mechanics of materials approach, thermal and moisture coefficients, Halpin-Tsai equations for elastic constants, Ultimate strengths of unidirectional lamina.

UNIT- III

Lamina Constitutive Equations: Macroscopic viewpoint, generalized Hooke's Law, reduction to homogeneous orthotropic lamina, orthotropic stiffness and compliance matrix, engineering elastic constants of a lamina, stress and strain transformations, Engineering constants of an angle lamina. Theories of failure- Maximum stress and strain criteria, Hill's criterion for anisotropic materials, Tsai-Hill and Tsai-Wu failure criteria.

UNIT - IV

Macro-mechanical Analysis of laminate: Introduction, code, displacement field, Kirchoff hypothesis – Classical Laminate Theory, A, B, & D matrices, Invariants, coupling interactions, balanced laminates, symmetric laminates, angle ply laminates, cross ply laminates, laminate structural moduli, determination of lamina stresses within laminates, laminate analysis using computer tools, Failure criterion.

UNIT - V

Manufacturing of Composites: Manufacturing process of epoxy resins and fibers, polymer matrix composites (PMCs) – hand lay-up, spray technique, filament winding, pultrusion, resin transfer molding (RTM), bag molding, injection molding, sandwich mold composites (SMC). Manufacturing of metal matrix composites (MMCs) – solid state, liquid state, vapor state processing. Ceramic matrix composites (CMCs) – hot pressing, reaction bonding process, infiltration technique, direct oxidation. Interfaces in composites.

Text Books:

1. R.M. Jones. Mechanics of Composite Materials. 2 nd ed. CRC press. 2018.
2. B.D. Agarwal et.al. Analysis and performance of fiber composites. 3rd ed. Wiley Sons, 2013.
3. P.K. Mallick. Fiber Reinforced Composites Materials, Manufacturing, and Design. 3rd ed. Taylor & Francis, 2007.

Suggested Reading:

1. Madhujit Mukhopadhyay. Mechanics of Composite Materials and Structures. Universities Press, 2022.
2. Ever J Barbero. Introduction to composite materials design.3rd ed. CRC Press, 2018.
3. M.W. Hyer. Stress Analysis of Fibre Reinforced Composite Materials. DEStech Publications, Inc, 2009

26MEE107

COMPUTATIONAL METHODS IN ENGINEERING

(Programme Elective – III)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:

This Course aims to

1. Basic equations and concept of Taylor series.
2. Solve linear linear algebraic equations.
3. Concept of PDEs with examples.
4. Basic concepts of FEM.
5. Importance of FVM.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Apply Taylor series of expansion for problems.
2. Solve simultaneous linear equations with various methods.
3. Classify PDEs based on the applications.
4. Relate real time applications using FEM.
5. Utilize FVM for heat transfer problems.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	1	2	1
CO2	3	1	2	2
CO3	2	1	1	2
CO4	3	1	2	2
CO5	3	1	2	2

UNIT - I

Introduction to Engineering Computation: Error analysis**,** Finite difference formula using Taylor series expansions: forwards, backward and center difference, numerical precision,

Differentiation of Lagrange polynomials, Simpson's rule, Gauss-quadrature rule, Romberg method and error propagation

UNIT - II

Numerical Methods in Linear Algebra: iterative solution techniques for simultaneous linear algebraic equations: Jacobi method, Gauss Seidel method, Gauss elimination method, LU Decomposition method and QR method.

UNIT- III

Classification of PDEs: Partial Differential Equations - Classification of PDEs, Elliptic equations, Parabolic equations (Transient diffusion equation), Hyperbolic equations (wave equation), Initial and boundary conditions.

UNIT - IV

Fundamentals of Finite Element Method: Historical background, FEA Procedure, Element Types, Shape Functions (Interpolation), Stiffness Matrix, Boundary Conditions (BCs), Galerkin Method. (no numerical).

UNIT - V

Finite Volume Method: Introduction to Finite volume method, finite difference vs. finite volume, Finite volume formulations for diffusion equation, convection diffusion equation, Staggered grids, SIMPLE and SIMPLE R algorithms.

Text Books:

1. S. P. Venkateshan, Prasanna Swaminathan, “Computational Methods in Engineering”, Academic Pr, 2013.
2. Tirupathi Chandrupatla , Ashok Belegundu, “Introduction to Finite Elements in Engineering”, Cambridge University, 2021.
3. H. K. Versteeg and Malala Shekara, “Introduction to Finite Volume Method”, Pearson, 2015.

Suggested Reading:

1. S. P. Venkateshan, Prasanna Swaminathan, “Computational Methods in Engineering”, Springer, 2023.
2. J.N.Reddy, “Introduction to Finite Element Method”. McGraw Hill, 2020.
3. John D. Anderson, “Computational Fluid Dynamics the Basics with Applications”, McGraw Hill, 2017.

26MEE108

ADVANCED OPTIMIZATION TECHNIQUES

(Programme Elective – III)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:

This course aims to

1. Provide knowledge for the formulation of LPP models
2. Provide in depth understanding of Transportation and Assignment techniques
3. Familiarize the procedure of Project Management along with CPMand PERT techniques
4. Make the students understand the concepts of queuing theory and inventory models
5. Make the students understand sequencing techniques and game theory

Course Outcomes:

Upon completion of this course, students will be able to:

1. Formulate a linear programming problem (LPP) and Integer Programming
2. Build and solve Transportation Models and Assignment Models.
3. Apply project management techniques like CPM and PERT to plan and execute project successfully
4. Apply Nonlinear programming
5. Apply queuing. sequencing models and game theory in industries

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	1	2	1
CO2	2	1	2	1
CO3	1	1	2	1
CO4	1	1	2	1
CO5	2	1	2	1

UNIT - I

Operations Research: Definition, scope, Models, Linear programming problems, Formulation, Graphical Method, Simplex Method, and Duality in simplex.

Integer Programming: Modelling optimization problems using binary variables; solution of integer programming problems: cutting plane method and branch -and – bound method

UNIT - II

Transportation Models: Finding an initial feasible solution - North West Corner Method, Least Cost Method, Vogel's Approximation Method, Finding the optimal solution, Special cases in Transportation problems - Unbalanced Transportation problem, Degeneracy in Transportation, Profit Maximization in Transportation.

UNIT- III

Project Management: Definition, Procedure and Objectives of Project Management, Differences between PERT and CPM, Rules for drawing Network diagram, Scheduling the activities,

Fulkerson's rule, Earliest and Latest times, Determination of ES and EF times in forward path, LS & LF times in

backward path, Determination of critical path, duration of the project, free float, independent float and Total float, crashing of network.

UNIT – IV

Non-linear Programming: Convex and concave functions, theory of unconstrained optimization ,Necessary and sufficient conditions for extrema ; theory of constrained optimization : Lagrangean method , Kuhn -Tucker conditions.

UNIT - V

Queuing Theory: Kendols Notation, single server models, Inventory control - deterministic inventory models - Probabilistic inventory control models.

Sequencing Models: Introduction, General assumptions, processing 'n' jobs through two Machines, processing 'n' jobs through three machines. Game Theory – definition saddle point Principle of Dominance.

Text Books:

1. H.A. Taha, "Operations Research, An Introduction", PHI, 2008
2. H.M. Wagner, "Principles of Operations Research", PHI, Delhi, 1982
3. J.C. Pant, "Introduction to Optimization: Operations Research", Jain Brothers, Delhi,2008

Suggested Reading:

1. Hitler Libermann, "Operations Research", McGraw Hill Pub. 2009
2. Pannerselvam, "Operations Research", Prentice Hall of India 2010
3. Harvey M Wagner,"Principles of Operations Research", Prentice Hall of India2010

26MEE109

FRACTURE MECHANICS

(Programme Elective – III)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to

1. Make students understand the Classification of fracture
2. Provide the importance of crack tip
3. Demonstrate the experimental setup while performing standard test
4. Give the students understanding of About R curve
5. Familiarize with the Fatigue crack propagation.

Course Outcomes: At the end of the course, student will be able to

1. Analyze the fracture mechanism
2. Gain familiarity with the different modes of failure under the presence of crack
3. Establish specimen size in accordance with the standard procedures
4. Distinguish between Plane stress fracture toughness and Plane strain fracture toughness.
5. Accomplish the relationship between crack propagation and stress intensity factor.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	2	2	1
CO2	2	2	2	-
CO3	2	2	2	-
CO4	2	2	2	-
CO5	2	2	2	-

UNIT - I

Introduction: Crack in a structure – Griffith criterion

Mechanism of Fracture and Crack Growth: cleavage fracture – ductile fracture fatigue cracking – service failure analysis

UNIT - II

Elastic Crack Tip Stress Field: Solution to crack problems – effect of finite size stress intensity factor – special cases

Crack Tip Plastic Zone: Irwin plastic zone correction – actual shape of plasticzone

UNIT- III

Energy Principle: Energy release rate – criterion for crack growth – J integral

Plane Strain Fracture Toughness: Standard test – size requirement – nonlinearity

UNIT - IV

Plane Stress and Transitional Behavior: concept of plane stress – R curve concept – thickness effect – plane stress testing

.**Elastic Plastic Fracture:** crack tip opening displacement.

UNIT - V

Fatigue Crack Propagation: Crack growth and stress intensity factor – factors affecting crack propagation – var-

iable amplitude service loading and its numerical retardation model

Text Books:

1. David Broek ,“Elementary Engineering Fracture Mechanics, Kluwer Academic Publishers , The Hague – 1984.
2. Prashant Kumar., “Elements of fracture mechanics”, Mc Graw Hill Education (India) Private Limited, New Delhi - 2014.
3. T.L. Anderson, “Fracture Mechanics - Fundamentals and Applications”, 3/e, Taylor and Francis Group, 2005

Suggested Reading:

1. R.N.L.Smith, “Basic Fracture Mechanics”, Butterworth Heinemann Publications, 1991.
2. K. Ramesh,” e-Book on Engineering Fracture Mechanics”, IIT Madras, 2007. URL:http://apm.iitm.ac.in/smlab/kramesh/book_4.htm
3. K. R.Y. Simha, “Fracture Mechanics for Modern Engineering Design”, Universities Press (India) Limited, 2001

26MEE110

DIGITAL TWIN AND INDUSTRY 5.0
(Programme Elective – IV)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:
To make the students to
1. To understand the fundamental principles and concepts of digital twin technology.
2. To apply digital twin techniques to analyse and optimize complex systems.
3. To develop skills in designing and implementing digital twin models for real world applications.
4. To evaluate the benefits and limitations of digital twin technology in various industries.
5. To critically analyse and interpret data obtained from digital twin simulations.

Course Outcomes:
Upon completion of this course, students will be able to:
1. Design and apply Digital Twin Technology using real-time systems and virtual models for industrial innovation.
2. Apply Digital Twin concepts in discrete and process industries for simulation, data analysis, and improving production, safety, and automation systems..
3. Understand and apply Industry 5.0 principles, smart manufacturing, and IoT-based systems to enhance industrial efficiency and human-centric innovation.
4. Ability to understand and apply Digital Twin architecture, modeling, and data integration, and analyze its use through real-world case studies in industry.
5. Ability to evaluate Digital Twin applications in enhancing quality, efficiency, safety, and productivity

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	2	1	2
CO2	3	3	3	2
CO3	3	2	2	1
CO4	3	1	2	2
CO5	3	3	3	3

UNIT - I
Introduction to Digital Twin and Enabling Technologies : Definition of Digital Twin, types of industry and key requirements, importance and applications in process, product, and service industries, history of Digital Twin, role of Digital Twin Technology (DTT) in industrial innovation, technologies and tools enabling Digital Twin, virtual CAD models, control parameters, real-time systems, handshaking through internet, cyber-physical systems.

UNIT - II
Digital Twin in Discrete and Process : Industries Basics and trends in discrete industry, control system requirements in discrete industry, digital twin of a product, digital thread in discrete industry, data collection and analysis for product and production improvements, automation simulation, digital enterprise. Basics and trends in process industry, control system requirements in process industry, digital twin of a plant, digital thread in

process industry, data collection and analysis for process improvements, process safety, automation simulation, digital enterprise.

UNIT- III

Industry 5.0 and Smart Manufacturing: Industrial revolutions overview, definition and principles of Industry 5.0, applications of Industry 5.0 in process and discrete industries, benefits and challenges of Industry 5.0, smart manufacturing, Internet of Things 5.0, industrial gateways, basics of communication requirements, cognitive systems in Industry 5.0..

UNIT - IV

Digital Twin Architecture, Modeling and Implementation: Digital Twin architecture (physical–digital integration framework),Layers of Digital Twin (data, model, communication, application layers),data collection using sensors,Data processing and synchronization,Basic communication and data exchange,Real-time monitoring and control, Overview of Digital Twin platforms and tools, Case studies: product design, manufacturing systems, and plant operations

UNIT - V

Benefits and Applications of Digital Twin: Improvement in product quality, enhancement of production processes and process safety, identifying bottlenecks and improving efficiency, achieving production flexibility, continuous prediction and tuning of processes through simulation, reducing time to market.

Text Books:

1. Alp Ustundag and Emre Cevikcan, “Industry 4.0: Managing the Digital Transformation”, Springer Series in Advanced Manufacturing., Switzerland, 2018
2. Andrew Yeh Chris Nee, Fei Tao, and Meng Zhang, “Digital Twin Driven Smart Manufacturing”, Elsevier Science., United States, 2019
3. Uthayan Elangovan, Industry 5.0: The Future of the Industrial Economy, CRC Press,2022.

Suggested Reading:

1. Alasdair Gilchrist, “Industry 4.0: The Industrial Internet of Things”, Apress., United States ,2015 .
2. https://nptel.ac.in/courses/110/106/110106169 – NPTEL: Digital Transformation Strategy (IIT Roorkee) – includes modules on Digital Twin and smart industry practices.
3. https://www.coursera.org/learn/digital-twin – Coursera: Digital Twins: Implementation (by University of Colorado) – practical insights into Digital Twin applications. .

26MEE111

DESIGN FOR MANUFACTURING AND ASSEMBLY

(Programme Elective – IV)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives:

This course aims to

1. Make students understand the need for design of a product
2. Understand the selection of material on the basis of manufacturing process
3. Familiarize various fabrication procedures
4. Reduce the manufacturing / process time
5. Make design according to ergonomics

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand the product development cycle
2. Know the manufacturing issues that must be considered in the mechanical engineering design process
3. Know the effect of manufacturing process and assembly operations on the product
4. Know the principles of assembly to minimize the assembly time
5. Be familiar with tools and methods to facilitate development of manufacturing mechanical designs

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	1	1	3	2
CO2	2	1	2	1
CO3	1	1	2	1
CO4	3	2	2	2
CO5	2	1	3	2

UNIT - I

Introduction: Need Identification and Problem Definition, Concept Generation and Evaluation, Embodiment Design, Selection of Materials and Shapes. Introduction to Precision Engineering.

Geometric Dimensioning & Tolerances: Introduction, Basic concepts and applications, Method of representation

UNIT - II

Selection of Engineering Materials: Classification of Engineering Materials (Metals, Polymers, Ceramics, Composites). Chemical Properties (Corrosion, Oxidation, Wear Resistance).

Selection of Materials – I: Material property charts, performance indices, Ashby approach

Selection of Materials – II: Multi-objective selection, constraints, optimization methods

UNIT- III

Selection of Shapes: Structural efficiency, section modulus, stiffness vs weight considerations.

Cost Analysis in Material Selection: Material cost, processing cost, lifecycle cost

Environmental & Sustainability Aspects: Eco-friendly materials, recyclability, carbon footprint

Case Studies – I: Material selection in automotive, aerospace, and biomedical applications

Case Studies – II: Real-world design problems involving material-shape-process integration

UNIT - IV

Selection of Manufacturing Processes: Design for Sheet Metal Forming Processes, Design for Machining, Design for Powder Metallurgy, Design for Plastics, Design for Polymer Processing, design for jigs and fixtures

Co- selection of Materials and Processes, Case- Studies – III

UNIT – V

Design for Assembly: Review of Assembly Processes, Design for Welding – I, Design for Welding – II, Design for Brazing and Soldering, Design for Adhesive Bonding, Design for Joining of Polymers, Design for Heat Treatment, Case- Studies – IV

Text Books:

1. M F Ashby and K Johnson, "Materials and Design - The art and science of material selection in product design", Butterworth- Heinemann, 03.
2. G Dieter, Engineering "Design - a materials and processing approach", McGraw Hill,NY,

Suggested Reading:

1. T H Courtney, "Mechanical Behavior of Materials", McGraw Hill, NY, 00.
2. G Boothroyd, P Dewhurst and W Knight, "Product design for manufacture and assembly", John Wiley, NY: Marcel Dekkar, 1994.

26MEE112

MACHINE LEARNING FOR INTELLIGENT SYSTEMS

(Programme Elective – IV)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to cover:

1. Basic machine learning techniques, regression modeling, and evaluation metrics.
2. Classification methods including Support Vector Machines and ensemble learning.
3. Clustering methods and dimensionality reduction for data analysis.
4. The basics of neural networks and their practical implementations.
5. Deep learning architectures and reinforcement learning paradigms

Course Outcomes:

Upon completion of this course, students will be able to:

1. Distinguish between different learning paradigms and apply linear regression to model data.
2. Develop classification models using decision trees, SVM, and ensemble techniques.
3. Implement clustering algorithms and apply PCA for dimensionality reduction in robotic guidance.
4. Design and train multi-layer perceptron networks using back propagation.
5. Evaluate the performance of convolutional networks, recurrent networks, and reinforcement learning in intelligent systems.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	3	2	2	2
CO 2	3	3	2	2
CO 3	3	3	2	2
CO 4	3	3	3	2
CO 5	3	3	3	2

UNIT - I

Fundamentals Of Machine Learning

Introduction to learning – types of machine learning, classification vs regression. Evaluation metrics and loss functions for classification and regression. Linear regression concepts. Applications of AI in robotics.

UNIT - II

Classification Methods

Support Vector Machine (SVM) algorithm. Learning with trees – decision trees, constructing decision trees, classification examples. Ensemble learning principles – boosting, bagging, and random forests.

UNIT- III

Clustering And Dimensionality Reduction

Introduction to clustering, types of clustering – agglomerative and k-means clustering, application study of k-means clustering. Principal Component Analysis (PCA), feature selection using PCA – case study in robot guidance.

UNIT - IV

Neural Networks And Applications

Neural networks – fundamentals of the perceptron, multi-layer perceptron (MLP). Backpropagation of error,

deriving backpropagation, practical implementation of MLP. Application case study of neural networks in robotics.

UNIT - V

Deep Learning And Reinforcement Learning

Introduction to deep learning – convolutional neural networks (CNN), recurrent neural networks (RNN). Reinforcement learning – examples, Markov decision process, major components of reinforcement learning (RL). Application case study of RL in robotics

Text Books:

1. Stephen Marsland, "Machine Learning – An Algorithmic Perspective", Chapman and Hall/CRC Machine Learning and Pattern Recognition Series, Second Edition, 2023.
2. Tom M Mitchell, "Machine Learning", McGraw Hill Education, 2021.
3. Ethem Alpaydin, "Introduction to Machine Learning", Adaptive Computation and Machine Learning Series, MIT Press, 4th Edition, 2020.

Suggested Reading:

1. Peter Flach, "Machine Learning: The Art and Science of Algorithms that Make Sense of Data", Cambridge University Press, First Edition, 2017.
2. Jason Bell, "Machine learning – Hands on for Developers and Technical Professionals", Wiley, First Edition, 2020

26MEC109

COMPUTER AIDED ENGINEERING LAB

Instruction	3 L Hours per Week
Duration of SEE	--
SEE	--
CIE	50 Marks
Credits	1.5

Course Objectives:

This course aims to

1. understand the fundamentals of Finite Element Analysis (FEA) using ANSYS
2. develop skills in modeling and meshing engineering components for simulation.
3. perform structural, thermal, and vibration analysis using ANSYS tools.
4. interpret and validate simulation results for engineering applications.
5. apply CAE techniques for design analysis and optimization in industrial problems

Course Outcomes:

Upon completion of this course, students will be able to:

1. Analyze structural behavior of bars, trusses, beams under various boundary conditions.
2. Evaluate behavior of engineering components under plane stress and plane strain conditions.
3. Perform thermal analysis to determine temperature distribution and heat flux in engineering applications.
4. Conduct modal and buckling analysis for stability and vibration assessment of structures.
5. Simulate laminar and compressible fluid flow problems.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	2	2	2	2
CO2	2	2	2	2
CO3	2	2	2	2
CO4	2	2	2	2
CO5	2	2	2	2

List of Exercises:

1. Introduction to Finite Element Analysis Software
2. Study Stepped bar for displacement, stress and reaction forces
3. Analysis of Truss with various cross sections and materials
4. Compute the Shear force and bending moment diagrams of beam element
5. Static analysis of plate with a hole under plane stress,
6. Analyze an octagonal pipe under plane strain.
7. Study axisymmetric loading on the in-plane members
8. Steady state thermal analysis of industrial chimney
9. Study of temperature distribution, heat flux through the automobile fin
10. Static analysis of a composite plate
11. Modal and Buckling analysis of a beam
12. Study of laminar flow over a flat plat
13. Study of compressible flow through a nozzle

Note: Out of the above 13 experiments, any **ten (10)** experiments have to be carried out.

Text Books:

1. R. Tirupathi, Chandrupatla and B.D. Ashok, "Introduction of Finite Element in Engineering", Prentice Hall of India, 2004
2. David.V.Hutton, "Fundamentals of Finite Element Analysis", Tata McGrawHill,2003

Suggested Reading:

1. Robert Cook , "Concepts and applications of finite element analysis", 4/e, John Wiley and sons, 2009
2. S.S. Rao, ,"The Finite Element Methods in Engineering", 2 /e, Pergamon Press, 2001

26MEC110

MECHANICAL DESIGN AND ANALYSIS LABORATORY

Instruction	3 L Hours per Week
Duration of SEE	--
SEE	--
CIE	50 Marks
Credits	1.5

Objectives: To make the students

1. Understand the MATLAB environment and commands.
2. Being able to do simple calculations using MATLAB.
3. Being able to carry out simple numerical computations and analyses using MATLAB.
4. Being able to represent mathematical object as data structure.
5. Ability to formulate mechanical engineering problems in a mathematical form and appropriate for subsequent computational treatment.

Outcomes: At the end of the course, student will be able to

1. Apply MATLAB programming to perform arithmetic operations, matrix manipulations, and solve engineering problems using built-in functions and scripts.
2. Analyze and solve systems of linear equations using numerical techniques such as Gaussian elimination, LU decomposition, and iterative methods like Jacobi and Gauss-Seidel.
3. Evaluate stress distributions in thick-walled cylinders and related mechanical systems using analytical methods (Lame's theory) and computational tools.
4. Model and analyze engineering problems involving plates, vibrations, and dynamic systems using numerical methods such as Finite Difference Method (FDM) and time integration techniques.
5. Assess fracture behaviour and structural response by computing stress intensity factors, energy release rates, natural frequencies, and mode shapes using numerical and computational approaches.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO1	3	2	2	2
CO2	3	2	2	1
CO3	3	2	3	2
CO4	3	2	3	2
CO5	3	2	3	2

List of Exercises:

1. MATLAB basics programs: Arithmetic operations, elementary math build in functions, Arrays, random number generation polynomials, system of linear equations, and programming in MATLAB.
2. Determine the Eigen values and Eigen vectors of given matrices.
3. Using Gaussian elimination/ Choksi factorization system of linear equations.
4. Using Jacobi/ Gauss siedel method to find the solutions to equations/matrices.
5. To perform an numerical analysis of thick-walled cylinders by:

(a) Evaluating radial and hoop stress distributions under internal and external pressures using Lame's theory.
(b) Simulating compound cylinder shrink fit to determine contact pressure and induced stresses.
(c) Modeling autofrettage process to estimate elastic–plastic behavior and residual stress distribution.
(d) Comparing all cases to understand stress redistribution and structural strengthening mechanisms in pressure vessels using computational methods in MATLAB.

6. To analyze the behavior of plates by computing and visualizing:
a. Deflection of a rectangular plate in one direction (1D FDM).
b. Deflection of a plate in two directions (2D FDM).
c. Thermal stress distribution due to temperature gradients.
d. Deflection of a circular plate under uniform load, and to compare numerical and analytical solutions wherever applicable.

7. To analyze fracture behavior of materials by:
a) Computing critical stress for crack propagation using Griffith theory
b) Evaluating Stress Intensity Factor (SIF) for edge and center cracks
c) Calculating strain energy release rate (G) and comparing with critical value.
d) Estimating the J-integral numerically and verifying its path independence.

8. To determine natural frequencies and mode shapes of structural systems by:
a) Solving the eigenvalue problem for longitudinal vibration of a rod using MATLAB.
b) Analysing lateral vibration of a beam using finite element method (FEM).
c) Implementing eigenvalue extraction techniques (Power method and Subspace iteration) and comparing results with MATLAB's built-in eigenvalue solver.

9. To analyze the dynamic response of structures by:
a) Solving single degree of freedom (SDOF) systems under free and forced vibration
b) Implementing time integration methods (Central Difference, Newmark-β, Wilson-θ)
c) Comparing their stability and accuracy
d) Computing response using mode superposition method.

10. To analyze the dynamic response of mechanical systems by incorporating Rayleigh damping into time integration methods (Central Difference, Newmark-β, Wilson-θ) and studying its effect on system response.

Text Books:

1) K. Russell, Q. J. Shen, and R. S. Sodhi, Mechanism Design: Visual and Programmable Approaches Using MATLAB and Simscape Multibody, 2nd ed. Boca Raton, FL, USA: CRC Press, 2025.
2) R. S. Sodhi, K. Russell, and J. Q. Shen, Kinematics and Dynamics of Mechanical Systems: Implementation in MATLAB and Simscape Multibody, 3rd ed. Boca Raton, FL, USA: CRC Press, 2023.
3) Applied Numerical Methods with MATLAB for Engineers and Scientists by Steven C. Chapra, 2000.

Reference Books / Resources:

1) D. B. Marghitu, H. Ghaednia, and J. Zhao, Mechanical Simulation with MATLAB®. Cham, Switzerland: Springer International Publishing, 2021.

26ME C111

MINI PROJECT WITH SEMINAR

Instruction	4 L Hours per Week
Duration of SEE	--
SEE	--
CIE	50 Marks
Credits	1

Course objectives:

This course aims to:

1. The mini-project shall contain a clear statement of the research objectives, background of work,
2. literature review, techniques used, prospective deliverables, and detailed discussion on results,
3. conclusions and references.
4. Expose and practice of searching and referring the required literature.
5. Provide a good initiation for the student(s) towards R&D.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Formulate a specific problem and give solution
2. Develop model/models either theoretical/practical/numerical form
3. Solve, interpret/correlate the results and discussions
4. Conclude the results obtained
5. Write the documentation in standard format

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO1	3	1	3	1
CO2	3	1	3	1
CO3	3	1	3	1
CO4	3	2	3	1
CO5	3	3	2	1

Guidelines:

1. As part of the curriculum in the II- semester of the program each students shall do a mini project, generally comprising about three to four weeks of prior reading, twelve weeks of active research, and finally a presentation of their work for assessment.
2. Each student will be allotted to a faculty supervisor for mentoring.
3. Mini projects should present students with an accessible challenge on which to demonstrate competence in research techniques, plus the opportunity to contribute something more original.
4. Mini projects shall have interdisciplinary/ industry relevance.
5. The students can select a mathematical modelling based/Experimental investigations or Numerical modelling.
6. All the investigations are clearly stated and documented with the reasons/explanations.
7. The mini-project shall contain a clear statement of the research objectives, background of work, literature review, techniques used, prospective deliverables, and detailed discussion on results, conclusions and references.

Department committee: Supervisor and two faculty coordinators

Guidelines for awarding marks in CIE (Continuous Internal Evaluation): Max. Marks:50		
Evaluation by	**Max. Marks**	**Evaluation Criteria / Parameter**
Supervisor	20	Progress and Review
	05	Report
Department Committee	05	Relevance of the Topic
	05	PPT Preparation
	05	Presentation
	05	Question and Answers
	05	Report Preparation

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M.E. (CAD/CAM)

SEMESTER – III

S.no	Course Code	Title of the Course	Scheme of Instruction			Scheme of Examination			Credits
			Hours Per Week			Duration of SEE in Hours	Maximum Marks		
			L	T	P/D		CIE	SEE	
THEORY									
1		Program Elective -V	3	--	--	3	40	60	3
2		Open Elective	3	--	--	3	40	60	3
3		Audit Course-2	2	--	--	2	--	50	Non - Credit
DISSERTATION									
4	26MEC112	Industrial Project /Dissertation Phase I	--	--	20	--	100	--	10
Total			**8**	**--**	**20**	**8**	**180**	**170**	**16**
Clock Hours Per Week: 28									

L: Lecture **D: Drawing** **CIE: Continuous Internal Evaluation**
T: Tutorial **P: Practical/Project Seminar/Dissertation** **SEE: Semester End Examination**

Program Elective - V		Open Elective	
26MEE113	Design For Sustainability and Safety	26CEO101	Cost Management of Engineering Projects
26MEE114	Automation In Manufacturing	26EEO104	Waste to Energy
26MEE115	Design Thinking and Process Planning	26CSO101	Business Analytics

26MEE113

DESIGN FOR SUSTAINABILITY AND SAFETY

(Programme Elective – V)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to cover:

1. Prepare the students for understanding the design for sustainable behaviour and design practices.
2. Sustainable design practices.
3. Provide the understanding of Lifecycle Assessment of Competing Product Designs.
4. Learn the hazard identification and risk assessment techniques.
5. Learn the Principles of safe design engineering.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand the foundations of sustainable design, including eco-design principles, lifecycle thinking, and sustainable product-service systems.
2. Analyze and apply design strategies to influence sustainable behavior using models like the Comprehensive action Determination Model (CADM).
3. Conduct lifecycle assessment (LCA) and environmentally responsible product evaluations to minimize environmental impact in design.
4. Apply design for safety principles, hazard identification techniques, and risk assessment methods to develop safe and reliable mechanical products and manufacturing systems.
5. Evaluate product safety, reliability, and compliance with engineering standards through failure analysis, simulation-based validation, and safety-oriented design approaches.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	2	2	3	3
CO 2	2	2	3	2
CO 3	1	2	3	3
CO 4	2	2	3	3
CO 5	1	2	3	3

UNIT - I

Foundations of Sustainable Design:

Understanding sustainability through design- Challenges and evolution toward sustainable solutions- Product lifecycle design and eco-efficient product-service systems (PSS)- Eco- design principles, strategies, and green design methodologies.

UNIT - II

Design for Sustainable Behaviour (DSB):

Behavioural change through design- Comprehensive Action Determination Model (CADM), Methods and tools to support sustainable behaviour- Individual cognitive vs context-driven approaches- Frameworks and future research in DSB.

UNIT- III

Design for Environment (DE):

Global, regional, and local environmental objectives- Lifecycle assessment (LCA) methods and tools, Environmentally responsible product assessment (e.g., AT&T method), Design techniques: minimizing material use, disassembly, recyclability, energy efficiency.

Product-Service Systems and Systemic Sustainability Design: Transition from product to integrated product-service design- Categories and practices of PSS for sustainability- Systemic design at regional/territorial levels- Regulatory frameworks, innovation levels, and evolution of sustainable design. Conceptualizing a Sustainable Product-Service System (PSS) Systemic Design Case Study: Regional Sustainability in Practice.

UNIT - IV

Design for Safety in Mechanical Engineering

Introduction to Design for Safety (DFS), safety considerations in mechanical product design, hazard identification and risk assessment techniques, failure analysis in engineering systems, ergonomics and human factors in design, safety standards and regulations in CAD/CAM applications, Design Failure Modes and Effects Analysis (DFMEA), safety factors in component design, simulation-based safety evaluation using CAD tools, and case studies on safe product and manufacturing system design.

UNIT - V

Advanced Safety Design and Risk Management

Principles of safe design engineering, machine safety and protective system design, reliability and risk-based design approaches, safety in automated manufacturing and robotics, digital simulation for safety validation, safety compliance in product lifecycle management, sustainable and environmentally safe design practices, predictive maintenance using digital tools, and industrial case studies on safety-oriented product and process design.

Text Books:

1. Ceschin, F., & Gaziulusoy, I. (2020). Design for sustainability: A multi-level framework from products to socio-technical system. Routledge.
2. Boothroyd, G. (1980). Design for assembly automation and product design. Marcel Dekker.

Suggested Reading:

1. Bralla, J. G. (1999). Design for manufacture handbook. McGraw-Hill..
2. Boothroyd, G., Heartz, W., & Nike, P. (1994). Product design for manufacture. Marcel Dekker.
3. B. S. Dhillon, P. (1995). An Introduction to Safety and Reliability Engineering,Publisher: CRC Press.

26MEE114

AUTOMATION IN MANUFACTURING

(Programme Elective – V)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to cover:

1. Provide the basic concepts of automation & its significance in manufacturing industries.
2. Understand automated flow lines.
3. Conceptualize & design following assembly line balancing.
4. Understand about automated material handling systems.
5. Elucidate the effective design and appropriate tests & inspection systems.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand the fundamentals, concepts, and impact of manufacturing automation strategies in modern industries.
2. Apply automation principles and control techniques in manufacturing systems and processes.
3. Design automated material handling and storage systems.
4. Analyze automated flow lines and assembly systems, and perform line balancing.
5. Utilize automated inspection and quality control methods in manufacturing environments.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	2	1	1	1
CO 2	1	1	1	1
CO 3	2	1	2	1
CO 4	2	1	2	1
CO 5	1	1	2	1

UNIT - I

Introduction: Definition of automation, Types of production, Functions of Manufacturing, Organization and Information Processing in Manufacturing, Production concepts and Mathematical Models, Automation Strategies, Production Economics: Costs in Manufacturing, Break-Even Analysis, Unit cost of production, Cost of Manufacturing Lead time and Work-in-process.

UNIT - II

Automation Production Lines: Automated Flow lines, Methods of Work part Transport, Transfer Mechanism, Buffer Storage, Control Functions, Automation for Machining Operations, Design and Fabrication Considerations. Analysis of Automated Flow Lines: General Terminology and Analysis, Analysis of Transfer Lines Without Storage, Partial Automation, Automated Flow Lines with Storage Buffers, Simulation of Automated Flow Lines.

UNIT- III

Assembly Systems and Line Balancing: The Assembly Process, Assembly Systems, Manual Assembly Lines, Methods of Line Balancing, Other ways to improve the Line Balancing, The Line Balancing Problem, Flexible Manual Assembly Lines. Automated Assembly Systems: Design for Automated Assembly, Types of Automated Assembly Systems, Part Feeding Devices, Analysis of Multi-station Assembly Machines, Analysis of a Single Station Assembly Machine.

UNIT - IV

Automated Materials Handling: The material handling function, Types of Material Handling Equipment, Analysis for Material Handling Systems, Design of the System, Conveyor Systems, Automated Guided Vehicle Systems. Automated Storage Systems: Storage System Performance, Automated Storage/Retrieval Systems, Carousel Storage Systems, Work-in-process Storage, Interfacing Handling and Storage with Manufacturing.

UNIT - V

Automated Inspection and Testing: Inspection and testing, Statistical Quality Control, Automated Inspection ,Principles and Methods, Sensor Technologies for Automated Inspection, Coordinate Measuring Machines, Other Contact Inspection Methods, Machine Vision, Other optical Inspection Methods. The Future Automated Factory: Trends in Manufacturing, The Future Automated Factory, Human Workers in the Future Automated Factory and the social impact.

Text Books:

1. Mikell P.Grover, "Automation, Production Systems and Computer Integrated Manufacturing", Pearson Education Asia, 2018.
2. Ray Asfahl, "Robots and manufacturing automation", John Wiley and Sons New York, 2010.

Suggested Reading:

1. N.Viswanadham and Y.Narahari, "Performance Modeling of Automated Manufacturing Systems", Printice Hall India Pvt. Ltd, 1992.
2. Stephen J. Derby, "Design of Automatic Machinery", Special Indian Edition, Marcel Decker, New York, Yesdee publishing Pvt. Ltd, Chennai, 2004.
3. Nanua Singh, "System Approach to Computer Integrated Manufacturing", Wiley & Sons Inc., 1996.

26MEE115

DESIGN THINKING AND PROCESS PLANNING

(Programme Elective – V)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to cover:

1. Provide the basic concepts of Design thinking.
2. Elucidate the steps to creating personas.
3. Provide an understanding of Fundamentals of Process Planning.
4. Facilitate the understanding ergonomical principles and advanced productivity techniques.
5. Provide the student with knowledge of Control Charts.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand design thinking and its phases as a tool of innovation.
2. Empathize on the needs of the users.
3. Define the problems for stimulating ideation.
4. Evaluate and recommend an effective Process Plan.
5. Plot control charts and apply quality control tools.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	3	3	3	1
CO 2	2	3	2	1
CO 3	1	3	2	1
CO 4	3	3	2	1
CO 5	2	3	3	1

UNIT - I

Introduction to Engineering & Design Thinking: Types of thinking – Linear thinking, lateral thinking, design thinking. Introduction to Design Thinking: Importance of Design Thinking & Human centric approach – Phases in design thinking process, five-stage model as iterative method, applications of design thinking in various domains**.**

Empathize phase: Understanding the unique needs of the user, empathize with the users, developing empathy towards people, empathy mapping.

UNIT - II

Define phase: Define the problem and interpret the result, analysis and synthesis, Personas – steps to creating personas, problem statement, affinity diagrams.

Ideation phase: What is ideation, need, uses, ideation methods; Brainstorming, rules for brainstorming; Mind maps, guidelines to create mind maps.

UNIT- III

Prototyping phase: Types of prototyping, guidelines for prototyping, storytelling, characteristics of good stories, reaching users through stories, importance of prototyping in design thinking; guidelines to write value proposition.

Testing phase: Necessity to test, user feedback, conducting a user test, how to test, desirable, feasible and

viable solutions.

UNIT - IV

Fundamentals of Process Planning: Need and significance of process planning, Process capability studies, Process sheets, Benefits and Types of Computer Aided process planning**.**

Process Selection and Planning: Selection of manufacturing process, co selection of materials and processes, Design for manufacturability and assembly, Estimation of costs for manufacture, value engineering in product design, Group technology, and concepts of concurrent engineering, quality function deployment and quality engineering.

UNIT - V

Quality Engineering: Control Charts-X, R, P, C charts. OC Curve, Acceptance Sampling, Kaizen, JIT, ISO-9000, Quality Concepts by Deming, Juran, Philip Crosby. Taguchi ' loss function. Six Sigma, Zero defects.

Text Books:

1. B.W. Niebel and A.B. Draper., Product Design and Process Engineering, Mc Graw Hill, Kogalkusha Ltd., Tokyo, 1974.
2. A.K. Chitale and Gupta, R.C., Product Design and Manufacturing, PHI, NewDelhi, 2004.

Suggested Reading:

1. M. Mahajan., Industrial Engineering and Production Management, Dhanpath Rai& Co., 2000.
2. Bhaskaran Gopalakrishnan, Product Design and Process Planning, Chapman and Hall, New York, 1994.

26CEO101

COST MANAGEMENT OF ENGINEERING PROJECTS

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to cover:

1. To enable the students to understand the concepts of Project management.
2. To provide knowledge on concepts of Project Planning and scheduling.
3. To create an awareness on Project Monitoring and Cost Analysis.
4. To provide adequate knowledge to the students on Recourse Management Costing-Variance Analysis.
5. To train the students with the concepts of Budgetary Control for cost management and to provide basic platform on Quantitative techniques for cost management.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Acquire in-depth knowledge about the concepts of project management and understand the principles of project management.
2. Determine the critical path of a typical project using CPM and PERT techniques.
3. Prepare a work break down plan and perform linear scheduling using various methods.
4. Solve problems of resource scheduling and levelling using network diagrams.
5. Learn the concepts of budgetary control and apply quantitative techniques for optimizing project cost.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	3	3	3	1
CO 2	2	3	2	1
CO 3	1	3	2	1
CO 4	3	3	2	1
CO 5	2	3	3	1

UNIT - I

Project Management: Introduction to project managements, stakeholders, roles, responsibilities and functional relationships. Principles of project management, objectives and project management system. Project team, organization, roles, and responsibilities. Concepts of project planning, monitoring, staffing, scheduling and controlling.

UNIT - II

Project Planning and Scheduling: Introduction for project planning, defining activities and their interdependency, time and resource estimation. Work break down structure. Linear scheduling methods-bar charts, Line of Balance (LOB), their limitations. Principles, definitions of network-based scheduling methods: CPM, PERT. Network representation, network analysis-forward and backward passes.

UNIT- III

Project Monitoring and Cost Analysis: Introduction-Cost concepts in decision making; relevant cost, Differential cost, Incremental cost and Opportunity cost. Objectives of a Costing System; Inventory valuation; Creation of a Database for operational control; Provision of data for Decision- Making, Time cost trade off Crashing

project schedules, its impact on time on time, cost. Project direct and indirect costs**.**

UNIT - IV

Resources Management and Costing-Variance Analysis: Planning, Enterprise Resource Planning, Resource scheduling and levelling. Total Quality Management and Theory of constraints. Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis**.**

Standard Costing and Variance Analysis. Pricing strategies: Pareto Analysis. Target costing, Life Cycle Costing. Costing of service sector. Just-in-time approach, Material Requirement.

UNIT - V

Boundary Budgetary Control: Flexible Budgets; Performance budgets; Zero-based budgets. Measurement of Divisional profitability pricing decisions including transfer pricing**.**

Quantitative techniques for cost management: Linear Programming, PERT/CPM, Transportation Assignment problems, Simulation, Learning Curve Theory.

Text Books:

1. Charles T Horngren "Cost Accounting A Managerial Emphasis", Pearson Education; 14 edition (2012),.
2. Charles T. Horngren and George Foster, "Advanced Management Accounting" Prentice-Hall; 6th Revised edition (1 February1987).
3. Robert S Kaplan Anthony A. Atkinson, "Management & Cost Accounting", Pearson; 2 edition (18 October1996)

Suggested Reading:

1. K. K Chitkara, "Construction Project Management: Planning, scheduling and controlling", Tata McGrawHill Education. (2004).
2. Kumar Neeraj Jha "Construction Project Management Theory and Practice", Pearson Education India; 2 edition (2015)

26EEO104

WASTE TO ENERGY
(Common All Branches)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to cover:
1. Know the various forms of waste.
2. Extraction of Energy from Waste.
3. Infer the Global and national scenario.

Course Outcomes:
Upon completion of this course, students will be able to:
1. Understand the concept of waste energy.
2. Explore the various Energy extraction options.
3. Describe the Energy Production methodology.
4. Explain the Environmental implications.
5. Compare and contrast waste energy productions by case studies.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	2	1	1	2
CO 2	3	1	2	2
CO 3	2	1	2	2
CO 4	2	2	1	3
CO 5	3	2	2	3

UNIT - I

Introduction: The Principles of Waste Management and Waste Utilization. Waste Management Hierarchy and 3R Principle of Reduce, Reuse and Recycle. Waste as a Resource and Alternate Energy source. Waste Sources & Characterization Waste production in different sectors such as domestic, industrial, agriculture, postconsumer, waste etc. Classification of waste – agro based, forest residues, domestic waste, industrial waste (hazardous and non-hazardous). Characterization of waste for energy utilization. Waste Selection criteria, Smart waste management systems (IoT-based monitoring).

UNIT - II

Energy Extraction Options: Landfill gas, collection and recovery. Refuse Derived Fuel (RDF) – fluff, briquettes, pellets. Alternate Fuel Resource (AFR) – production and use in Cement plants, Thermal power plants and Industrial boilers. Conversion of wastes fuel resources for other useful energy applications Energy from Plastic Wastes: Non-recyclable plastic wastes for energy recovery. Energy Recovery from waste and optimization of its use, benchmarking and standardization. Energy Analysis.

UNIT- III

Energy production Methodologies: Collection, segregation, transportation and storage requirements. Location and Siting of 'Waste Energy' plants. Industry Specific Applications: In-house use: sugar, distillery, pharmaceuticals, Pulp and paper, refinery and petrochemical industry and any other industry. Centralized and Decentralized Energy production, distribution and use. Comparison of Centralized and decentralized systems and its operations**.**

UNIT - IV

Environmental Implications: Environmental standards for Waste Energy Plant operations and gas clean-up. Savings on non-renewable fuel resources. Carbon Credits: Carbon foot calculations and carbon credits transfer mechanisms.

UNIT - V

Case Studies: Success/failures of waste energy Global Best Practices in Waste energy production distribution and use. Indian Scenario on Waste Energy production distribution and use in India. Success and Failures of Indian Waste Energy plants. Role of the Government in promoting 'Waste Energy ", Government policies & PPP models, Future trends: AI in waste management, circular economy.

Text Books:

1. "Industrial and Urban Waste Management in India", TERI Press.
2. Banwari Lal and Patwardhan, "Wealth from Waste: Trends and Technologies" TERI Press).
3. S.N Mukhopadhyay, "Fundamentals of waste and Environmental Engineering", TERIPress.
4. "Waste-to-Energy in Austria – White Book – Figures, Data Facts", 2nd edition, May 2010.

Suggested Reading:

1. CPCB Guidelines for Co-processing in Cement/Power/Steel Industry.
2. Report of the task Force on Waste Energy, Niti Ayog (Formerly Planning Commission) 2014.
3. Municipal Solid Waste Management Manual, CPHEEO, 2016
4. Gazette Notification on Waste Management Rules 2016.

S.No.	NPTEL Course Name	Instructor	Host Institute
1	Waste to Energy Conversion	Prof. P. Mondal	IIT Roorkee
Other Online Resources:			
1	https://nptel.ac.in/courses/103107125	-	-

26CSO101

BUSINESS ANALYTICS
(Open Elective)

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

PRE-REQUISITES: Basic of programming, basic mathematics**.**

Course Objectives: This course aims to cover:
1. Understanding the basic concepts of business analytics and applications.
2. Study various business analytics methods including predictive, prescriptive and descriptive analytics.
3. Prepare the students to model business data using various data mining, decision making methods.

Course Outcomes:
Upon completion of this course, students will be able to:
1. Identify and describe complex business problems in terms of analytical models.
2. Apply appropriate analytical methods to solve business problems and interpret the resulting metrics and measures to achieve stated objectives.
3. Illustrate descriptive, predictive and prescriptive analytics methods and techniques.
4. Model business data using data mining, forecasting, decision tree, and clustering techniques.
5. Design and evaluate viable data-driven solutions to complex business decision-making problems.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	3	1	3	2
CO 2	3	2	3	2
CO 3	2	2	3	2
CO 4	3	2	3	3
CO 5	3	3	3	3

UNIT - I
Introduction to Business Analytics: Introduction to Business Analytics, need and science of data driven decision making, Descriptive, predictive, prescriptive analytics and techniques, Big data analytics, Web and Social media analytics, Machine Learning algorithms, Generative AI , LLMs and Explainable AI (XAI) in business analytics, framework for decision making, challenges in data driven decision making and future.

UNIT - II
Descriptive Analytics: Introduction, data types and scales, types of measurement scales, population and samples, measures of central tendency, percentile, decile and quadrille, measures of variation, measures of shape-skewness, data visualization.

UNIT- III
Forecasting Techniques: Introduction, time-series data and components, forecasting accuracy, moving average method, single exponential smoothing, Holt's method, Holt-Winter model, Croston's forecasting method, regression model for forecasting, Auto regression models, auto-regressive moving process, ARIMA, Theil's coefficient**.**

UNIT - IV
Decision Trees: CHAID, Classification and Regression tree, splitting criteria, Ensemble methods, Random For-

est, XGBoost. Clustering: Distance and similarity measures used in clustering, Clustering algorithms, K-Means, Prescriptive Analytics- Linear Programming (LP) and LP model building.

UNIT - V

Six Sigma: Introduction, origin, 3-Sigma Vs Six-Sigma process, cost of poor quality, industry applications, six sigma measures, DPMO, yield, sigma score, DMAIC methodology, Six Sigma toolbox.

Text Books:

1. U Dinesh Kumar, "Business Analytics", Wiley Publications, 2nd Edition, 2022.
2. Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, "Business analytics Principles,Concepts, and Applications with SAS", Associate Publishers, 2015.

Suggested Reading:

1. S. Christian Albright, Wayne L. Winston, "Business Analytics - Data Analysis and Decision Making",6th Edition, Cengage, 2020.

ONLINE RESOURCES:

1. Coursera – Business Analytics Specialization (University of Pennsylvania, Wharton): https://www.coursera.org/specializations/business-analytics.
2. NPTEL – Business Analytics and Data Mining (IIT Roorkee): https://nptel.ac.in/courses/110107106
3. edX – Data Science and Analytics MicroMasters (MIT): https://www.edx.org/micromasters/mitx-statistics-and-data-science

26MEC112

INDUSTRIAL PROJECT / DISSERTATION PHASE - I

Instruction	20 Hours per Week
Duration of SEE	--
SEE	--
CIE	100 Marks
Credits	10

Course Objectives: This course aims to cover:

1. Orient the students to carry out literature survey and identify the problem statement.
2. Make the student devise a methodology on his own.
3. Facilitate the student to explore different software/hardware techniques.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Students will be exposed to self-learning various topics.
2. Students will learn to survey the literature such as books, national/ international referred journals and contact resource persons for the selected topic of research.
3. Students will learn to write technical reports.
4. Students will develop oral and written communication skills to present.
5. Student will defend their work in front of technically qualified audience.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	3	3	3	3
CO 2	3	3	3	3
CO 3	3	3	3	3
CO 4	3	3	2	3
CO 5	2	2	2	3

Guidelines:

1. The Project work will preferably be a problem with research potential and should involve scientific research, design, generation/collection and analysis of data, determining solution and must preferably bring out the individual contribution.
2. Seminar should be based on the area in which the candidate has undertaken the dissertation work.
3. The CIE shall include reviews and the preparation of report consisting of a detailedproblem statement and a literature review.
4. The preliminary results (if available) of the problem may also be discussed in the report.
5. The work has to be presented in front of the committee which consists of Head, Chairperson-BoS, Supervisor and Project coordinator.
6. The candidate has to be in regular contact with his supervisor and the topic of dissertation must be mutually decided by the guide and student.

Guidelines for awarding marks in CIE (Continuous Internal Evaluation): Max. Marks:100		
Evaluation by	**Max. Marks**	**Evaluation Criteria / Parameter**
Supervisor	30	Project Status / Review(s)
	20	Report
Department Review Committee	10	Relevance of the Topic
	10	PPT Preparation(s)
	10	Presentation(s)
	10	Question and Answers
	10	Report Preparation

Note: Department committee has to assess the progress of the student for every two weeks.

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY

R26 (In line with AICTE Model Curriculum) with effect from AY 2026-27

M.E. (CAD/CAM)

SEMESTER – IV

S.no	Course Code	Title of the Course	Scheme of Instruction			Scheme of Examination			Credits
			Hours Per Week			Duration of SEE in Hours	Maximum Marks		
			L	T	P/D		CIE	SEE	
THEORY									
9	26MEC113	Industrial Project / Dissertation Phase - II	--	--	32	Viva voce	100	100	16
Total			--	--	32	--	**100**	**100**	**16**
Clock Hours Per Week: 32									

L: Lecture **D: Drawing** **CIE: Continuous Internal Evaluation**
T: Tutorial **P: Practical/Project Seminar/Dissertation** **SEE: Semester End Examination**

Courses offered by MED to other departments		
S.no	**Course code**	**Title of the Course**
1	26MEO 101	Industrial Safety
2	26MEO 102	Introduction to Optimization Techniques
3	26MEO 103	Composite Materials
4	26MEO 104	Alternative energy sources
5	26MEO 105	Computational Fluid Dynamics
6	26MEO 106	Design Thinking For Business Solutions

26MEC113

INDUSTRIAL PROJECT / DISSERTATION PHASE - II

Instruction	32 Hours per Week
Duration of SEE	Viva-Voce
SEE	100 Marks
CIE	100 Marks
Credits	16

Course Objectives: This course aims to cover:

1. Orient the students towards scientific research, problem solving, design, generation/collection and analysis of data.
2. Make the student to realize the objectives and fulfil the aim of the project.
3. Enhance the technical writing skills and encourage to publish the findings.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Students will be able to use different experimental techniques and will be able to use different software/ computational/analytical tools.
2. Students will be able to design and develop an experimental set up/ equipment/test rig.
3. Students will be able to conduct tests on existing setups/equipment and draw logical conclusions from the results after analyzing them.
4. Students will be able to either work in a research environment or in an industrial environment.
5. Students will be conversant with technical report writing and will be able to present and convince their topic of study to the engineering community.

CO-PO Articulation Matrix

PO / CO	PO 1	PO 2	PO 3	PO 4
CO 1	3	3	3	3
CO 2	3	3	3	3
CO 3	3	3	3	3
CO 4	3	3	2	3
CO 5	2	2	2	3

Guidelines:

1. It is a continuation of Project work started in semester III.
2. The student has to submit the report in prescribed format and also present a seminar.
3. The dissertation should be presented in standard formats provided by the department.
4. The candidate has to prepare a detailed project report consisting of introduction of the problem, problem statement, literature review, objectives of the work, methodology (experimental set up or numerical details as the case may be) of solution and results and discussion.
5. The report must bring out the conclusions of the work and future scope for the study. The work has to be presented in front of the examiners panel consisting of an approved external examiner, an internal examiner (HoD and BoS Chair Person) guide/co-guide.
6. The candidate has to be in regular contact with his/her guide/co-guide.

Guidelines for awarding marks in CIE (Continuous Internal Evaluation): Max. Marks:100		
Evaluation by	**Max. Marks**	**Evaluation Criteria / Parameter**
Department Review Committee	05	Review 1
	10	Review 2
	10	Review 3
	15	Final presentation with the draft copy of the report standard format
	10	Submission of the report in a standard format
Supervisor	10	Regularity and Punctuality
	10	Work Progress
	10	Quality of the work which may lead to publications
	10	Analytical / Programming / Experimental Skills Preparation
	10	Report preparation in a standard format

Guidelines for awarding marks in SEE (Semester End Examination): Max. Marks: 100		
Evaluation by	**Max. Marks**	**Evaluation Criteria / Parameter**
External and Internal Examiner (s) together	20	Power Point Presentation
	40	Quality of thesis and evaluation
	20	Quality of the project 1. Innovations 2. Applications 3. Live Research Projects 4. Scope for future study 5. Application to society
	20	Viva-Voce

26MEO101

INDUSTRIAL SAFETY

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to cover:

1. Causes for industrial accidents, preventive steps to be taken, Factories act 1948 and 5S Techniques.
2. Fundamental concepts of Maintenance Engineering.
3. About Safety in advanced manufacturing systems.
4. The basic concepts and importance of fault tracing.
5. The steps involved in periodic and preventive maintenance of various industrial equipments.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Identify causes of industrial accidents and recommend preventive measures.
2. Select appropriate tools and practices for various maintenance procedures.
3. Apply different Safety measures in advanced manufacturing systems.
4. Diagnose faults in equipment such as machine tools, IC engines, and boilers.
5. Implement periodic and preventive maintenance for industrial equipment including motors, pumps, air compressors, and machine tools.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	3	3	3	3
CO 2	3	3	3	2
CO 3	3	1	3	2
CO 4	3	1	3	2
CO 5	3	2	3	3

UNIT - I

SAFETY MANAGEMENT CONCEPTS AND INDUSTRIAL SAFETY PRACTICES

Industrial Safety & Legal Aspects: Industrial accidents – causes, types, consequences, and preventive measures. Mechanical and electrical hazards and their control. Fire hazards, prevention and firefighting methods. Safety color codes and safety signage. Salient provisions of the Factories Act 1948 related to health, safety, and welfare.

Safety Audit: Types of safety audits – audit methodology, preparation of audit checklists, Non-Conformity Reporting (NCR). Analysis and interpretation of accident records and safety reports.

5S Techniques: Introduction, objectives, and elements of 5S (Sort, Set in order, Shine, Standardize, Sustain). Benefits of 5S in enhancing workplace safety, productivity, and efficiency.

UNIT - II

Fundamentals of Maintenance Engineering: Definition and objectives of maintenance engineering. Primary and secondary functions and responsibilities of the maintenance department. Types of maintenance (preventive, predictive, breakdown, corrective) and their applications. Tools and equipment used in maintenance activities. Maintenance cost and its relationship with replacement decisions and economy. Concept of service life and factors affecting the lifespan of equipment.

UNIT- III

Safety in advanced manufacturing systems: Machine safety in CNC, robotics, and Flexible Manufacturing Systems (FMS). Human–machine interaction safety. Safety in Industry 4.0 environments including cyber-physical systems, smart factories, and digital twins. Safety in additive manufacturing (powder handling and laser safety). Safety in material handling systems (conveyors, cranes, AGVs) and manufacturing processes (welding, casting, forging, machining). Electrical safety in automation and Lockout/Tagout (LOTO) procedures.

UNIT - IV

Fault Tracing: Concept and importance of fault tracing. Decision tree approach – need, structure, and applications. Sequence of fault-finding activities and systematic troubleshooting procedures. Development and representation of fault diagnosis using decision trees. Fault tracing in industrial equipment including machine tools, pumps, air compressors, internal combustion engines, boilers, and electrical motors. Types of faults in machine tools and their general causes.

UNIT - V

Maintenance and Condition Monitoring

Periodic and Preventive Maintenance: Periodic inspection, concept and need. Cleaning, servicing, and overhauling of mechanical components and electrical motors. Common motor faults and remedies. Preventive maintenance definition, steps, and advantages. Maintenance procedures for machine tools, pumps, air compressors, and DG sets.

Condition monitoring and basic concepts of Proactive maintenance for Industry 4.0.

Text Books:

1. L. M. Deshmukh, Industrial Safety Management, McGraw Hill Education, New Delhi, 1st Edition, 2010.
2. M.R. Sahoo, Industrial Safety Engineering, RK Publications, New Delhi, 1st Edition, 2015.
3. H. P. Garg, “Industrial Maintenance”, S. Chand and Company, may 1987.
4. Das Akhil Kumar, Principles of Industrial Safety Management Understanding the Ws of Safety at Work, Second edition, PHI Learning Pvt Ltd, Jan 2020

Suggested Reading:

1. Parth B. Shah, Industrial Safety and Maintenance Engineering, Technical publications, 2021.
2. Higgins & Morrow, “Maintenance Engineering Handbook”, McGraw-Hill Education Eighth Edition, February 2014.
3. M.P. Poonia, S.C. Sharma, Khanna Publishing House - Technology & Engineering, year 2019.

26MEO102

INTRODUCTION TO OPTIMIZATION TECHNIQUES

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to

1. Understand the LPP models.
2. Understand the Transportation and Assignment techniques.
3. Understand the procedure of Project Management along with CPM and PERT techniques.
4. Understand the concepts of queuing theory and inventory models.
5. Understand sequencing techniques.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Formulate a linear programming problems (LPP).
2. Build and solve Transportation Models and Assignment Models.
3. Apply project management techniques like CPM and PERT to plan and execute project successfully.
4. Apply queuing and inventory concepts in industrial applications.
5. Apply sequencing models in industries.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	3	1	3	1
CO 2	3	1	3	1
CO 3	1	1	3	2
CO 4	2	1	3	2
CO 5	2	1	3	2

UNIT - I

Operations Research: Definition, Scope, Models, Linear programming problems (LPP), Formulation, Graphical Method, and Simplex Method.

UNIT - II

Transportation Models: Finding an initial feasible solution, North West corner method, Least cost method, Vogel's approximation method, Finding the optimal solution, Special cases in transportation problems, Unbalanced transportation problem, Degeneracy in transportation, Profit maximization in transportation.

UNIT- III

Project Management: Definition, Procedure and objectives of project management, Differences between PERT and CPM, Rules for drawing network diagram, Scheduling the activities, Fulkerson's rule, Earliest and latest times, Determination of ES and EF times in forward path, LS & LF times in backward path, Determination of critical path, Duration of the project, Free float, Independent float and total float.

UNIT - IV

Queuing Theory and Inventory:: Kendols notation, Single server models, Inventory control, Deterministic inventory models, Probabilistic inventory control models.

UNIT - V

Sequencing Models: Introduction, Objectives, General assumptions, Processing 'n' jobs through two machines, Processing 'n' jobs through three machines**.**

Text Books:

1. H.A. Taha, Operations Research, An Introduction, PHI, 2008.
2. H.M. Wagner, Principles of Operations Research, PHI, Delhi, 1982.
3. J.C. Pant, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008.

Suggested Reading:

1. Hitler Libermann, Operations Research, McGraw Hill Pub, 2009.
2. Harvey M Wagner, Principles of Operations Research, Prentice Hall of India, 2010.

26MEO103

COMPOSITE MATERIALS

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to

1. Provide concepts of Composite materials and their constituents.
2. Explain the Classification of the reinforcements and matrix materials.
3. Provide Fabrication methods of metal matrix composites.
4. Explain manufacturing of Polymer matrix composites.
5. Elucidate Failure mechanisms in composite materials.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand composite materials and their reinforcements.
2. Summarize micro-mechanics approach as applied to UD lamina.
3. Apply fabrication methods of metal, ceramic and carbon matrix composites.
4. Apply fabrication methods of polymer matrix composites..
5. Analyze the lamina and laminate from failure perspective.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO 4
CO 1	3	1	3	1
CO 2	3	1	3	1
CO 3	3	2	3	1
CO 4	3	2	3	1
CO 5	3	1	3	1

UNIT - I

Introduction: Definition Classification and characteristics of Composite materials. Advantages and application of composites. Functional requirements of reinforcement and matrix. Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

UNIT - II

Reinforcements: Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers. Properties and applications of whiskers, particle reinforcements.

Mechanical Behaviour of composites: Rule of mixtures, Inverse rule of mixtures. Iso-strain and Iso-stress conditions.

UNIT- III

Processing of Metal Matrix Composites: Casting - Solid State diffusion technique, Cladding - Hot isostatic pressing. Properties and applications.

Processing of Ceramic Matrix Composites: Liquid Metal Infiltration - Liquid phase sintering.

Processing of Carbon - Carbon composites: Knitting, Braiding, Weaving. Properties and applications.

UNIT - IV

Processing of Polymer Matrix Composites: Preparation of Moulding compounds and prepregs - hand layup method - Autoclave method - Filament winding method - Compression moulding - Reaction injection moulding. Properties and applications.

UNIT - V

Strength: Lamina Failure Criteria, strength ratio, maximum stress criteria, maximum strain criteria, interactive failure criteria and hygrothermal failure. Laminate first ply failure -insight strength**.**

Text Books:

1. K.K.Chawla, "Composite Materials- Science and Engineering", 4th edition, Springer Verlag, 2019.
2. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007..
3. R.M. Jones. Mechanics of Composite Materials. 2 nd ed. CRC press. 2018.

Suggested Reading:

1. Deborah D.L. Chung, "Composite Materials Science and Applications" 2nd edition, Springer Verlag, 2010.
2. Sanjay K. Mazumdar, "Composites Manufacturing- materials, product and process engineering", 1st edition, CRC press, 2002.
3. Daniel Gay, "Composite Materials Design and Applications" 3rd edition, CRC press, 2015.

26MEO104

ALTERNATIVE ENERGY SOURCES

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to

1. Need and importance of non-conventional energy resources.
2. Extent of solar energy which can be utilized as energy resource.
3. Concept of wind energy and its merits and demerits.
4. Operating principles of geothermal energy and bio-energy.
5. Merits and demerits of tidal energy, wave energy and OTEC.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Understand the need for renewable energy sources in the context of environmental issues.
2. Apply the principles of solar energy for domestic and industrial usages.
3. Understand the working principle of wind power plants along with merits and demerits.
4. Describe the concepts of geothermal energy sources and biomass as a source of energy.
5. Explain the principles and impact of wave, tidal and OTEC plants on the environment.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	2	2	3	2
CO 2	3	2	3	1
CO 3	3	3	3	1
CO 4	3	2	3	1
CO 5	3	2	2	1

UNIT - I

Energy Sources: Energy characteristics, forms of energy, energy chain (route), energy sectors, Indian energy scenario, energy pricing in India, energy and environment, energy security, energy conservation and its importance, energy strategy for future, classification of energy sources, availability of conventional and non-conventional (renewable) energy sources, classification of RES - solar, wind, geothermal, bio-mass, ocean tidal, ocean wave and ocean thermal energy conversion (OTEC), advantages and limitations of conventional and renewable energy sources.

UNIT - II

Solar Energy: Solar radiation, solar thermal collectors, working of flat plate and concentrating (focusing) solar collectors and their limitations, comparison of flat plate and focusing collectors, applications of solar collectors - water heating, space heating, low temperature power generation, solar cookers, water pumping, SODIS, solar thermal power plant, advantages and limitations of solar energy systems, PV materials, PV cells and their manufacturing, space based solar power (SBSP), solar satellite system, advantages and disadvantages of SBSP..

UNIT- III

Wind Energy: Sources of wind, merits and demerits of wind energy, site selection for wind energy conversion system, wind turbine (wind mill), classification of wind mills, working principle horizontal axis and vertical axis windmills, horizontal vs vertical axis windmills, power extracted from the wind, effect of velocity on power generation, new developments and problems in operating large wind power generators.

UNIT - IV

Geothermal Energy: Layers in earth, resources of geothermal energy, hydrothermal, petrothermal and geopressure resources, advantages, disadvantages, applications and environmental effects of geothermal energy sources**.**

Biomass Energy: Resources, biogas and its composition, process of biogas generation, wet process and dry process, raw materials available for biogas fermentation, economical, social, environmental and health benefits of biogas utilization, selection of site and constructional techniques of a biogas plant, working of KVIC, Pragathi design, Janata and Deenbandu biogas plants, common operational problems, causes and remedies relating to a biogas plant.

UNIT - V

Tidal power: Tidal systems, site selection for tidal power plant, schematic layout of tidal power house, principle of operation of single basin and double basin tidal plants, advantages and disadvantages of tidal power.

Wave energy - Differences between tides and waves, advantages and disadvantages of wave power, problems associated with wave energy collection, working principle of wave energy conversion devices.

Ocean thermal energy conversion (OTEC) - OTEC power plants, location, open cycle and closed cycle OTEC plants, advantages, limitations and applications of OTEC, environmental impact of OTEC plants.

Text Books:

1. S. Hasan Saeed and D.K. Sharma, ―Non Conventional Energy Resources‖, S.K. Kataria & Sons, New Delhi, 2017.
2. Dr. R.K. Singal, ―Non Conventional Energy Resources‖, S.K. Kataria & Sons, New Delhi, 2005.

Suggested Reading:

1. K. M. Mittal, ―Non-Conventional Energy Systems‖, Wheeler Publishing Co. Ltd, New Delhi, 2003.
2. Shali Habibulla, ―Non-Conventional Energy Sources‖, State Institute of Vocational Education, Hyderabad, 2005
3. G.D. Rai, ―Non Conventional Energy Sources‖, Khanna Publishers, New Delhi, 2011.

26MEO105

COMPUTATIONAL FLUID DYNAMICS

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to

1. Basic equations and concept of CFD.
2. Concept of PDEs and finite difference methods.
3. Crank-Nihcolson, Implicit and Explicit methods & Jacobi, Gauss Seidel and ADI methods.
4. Various types of grid generation and errors in numerical solution.
5. Importance of FVM.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Derive CFD governing equations and turbulence models.
2. Apply different PDEs and know the importance of Taylor series of expansion.
3. Solve simultaneous linear equations with various methods.
4. Understand errors, stability, consistency and develop O,H and C grid generated models.
5. Utilize FVM for heat transfer problems.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	3	1	3	1
CO 2	3	1	3	1
CO 3	3	1	3	1
CO 4	3	1	3	1
CO 5	3	1	3	1

UNIT - I

Governing Equations: Continuity, Momentum and Energy equations, Navier Stokes equations, Reynolds and Favre averaged N – S equations. Introduction to turbulence, Turbulence models-mixing length model, K-å turbulence Model.

UNIT - II

Classification of PDEs: Elliptic, parabolic and hyperbolic equations, Initial and boundary conditions. Concepts of Finite difference methods – forward, backward and central difference, explicit, Implicit and Crank Nicholson.

UNIT- III

Finite Difference Solutions: Solution of simultaneous linear equations: Jacobi, Gauss Seidel, TDMA, ADI, solution for viscous incompressible flow using Vorticity Stream function method, MAC method.

UNIT - IV

Grid Generation: Grid Generation- Types of grid O,H,C. Coordinate transformation, Unstructured grid generation, Errors, Consistency, Stability analysis by von Neumann. Convergence criteria.

UNIT - V

Finite Volume Method: Introduction to Finite volume method, Finite volume formulations for diffusion equation, convection diffusion equation, Staggered grids SIMPLE and SIMPLE R algorithms.

Text Books:

1. P.S. Ghoshdastidar, Computational Fluid Dynamics and Heat Transfer, Cengage, 2017.
2. John D. Anderson, “Computational Fluid Dynamics”, Mc Graw Hill Inc., 2018.
3. H. K. Versteeg and Malala Shekara, “Introduction to Finite Volume Method”, Pearson, 2015

Suggested Reading:

1. K. Muralidhar and T. Sundararajan T., “Computational Fluid flow and Heat transfer”, Narosa Publishing House, 2003.
2. S.V. Patankar, “Numerical Heat transfer and Fluid flow”, Hemisphere Publishing Company, New York, 1980.

26MEO106

DESIGN THINKING FOR BUSINESS SOLUTIONS

Instruction	3 L Hours per Week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course aims to

1. Develop creative and human-centered problem-solving skills for business and organizational contexts.
2. Enable students to apply design thinking tools and techniques for identifying customer and stakeholder needs.
3. Foster collaborative ideation, prototyping, and solution development for real-world managerial and societal challenges.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Derive CFD governing equations and turbulence model Understand the concepts, principles, and phases of design thinking in business and organizational settings s.
2. Analyze customer and stakeholder needs using empathy-based approaches and problem identification techniques.
3. Define business and organizational problems using structured design thinking tools.
4. Generate innovative and feasible solutions through ideation and collaborative thinking methods..
5. Develop, prototype, test, and refine solutions for business, service, and societal applications.

CO-PO Articulation Matrix

PO / CO	PO1	PO2	PO3	PO4
CO 1	3	2	1	2
CO 2	3	3	2	2
CO 3	3	3	2	3
CO 4	2	3	2	2
CO 5	3	3	2	2

UNIT - I

Introduction to Thinking and Design Thinking: Thinking and behaviour; Types of thinking – Linear thinking, lateral thinking, systems thinking, and design thinking.

Introduction to Design Thinking – Importance of design thinking and human-centered approach; phases in the design thinking process; five-stage model as an iterative method; applications of design thinking in business, services, entrepreneurship, customer experience, and organizational problem-solving.

Case studies on business and service innovations.

UNIT - II

Empathize Phase: Understanding customer and stakeholder needs; empathizing with users; steps in empathize phase; developing empathy towards people; customer observation and interviews; assuming a beginner's mindset (What? Why?); immersion activity; body storming; customer journey mapping; stakeholder analysis.

Case studies.

UNIT- III

Define Phase: Defining the problem and interpreting results; analysis and synthesis; Personas – perspectives on personas and steps in creating personas; problem statements; affinity diagrams; empathy mapping; Point of View (POV); "How might we" questions; Why-How laddering; identifying business and organizational challenges using design thinking tools.

Case studies.

UNIT - IV

Ideation Phase: Concept of ideation; need and uses of ideation; ideation methods; brainstorming and rules for brainstorming; mind maps and guidelines for creating mind maps; ideation games; Six Thinking Hats; doodling and visual thinking techniques; collaborative idea generation; evaluating and selecting feasible solutions.
Case studies.

UNIT - V

Prototyping and Testing Phase: Types of prototyping; guidelines for prototyping; storytelling and its importance in communicating solutions; characteristics of good stories; value proposition and guidelines for developing value propositions; service and business solution prototyping.

Text Books:

1. Tim Brown, Change by Design: How Design Thinking Transforms Organizations and Inspires, 1st Edition, HarperCollins, 2009.
2. Michael Luchs, Scott Swan, Abbie Griffin, Design thinking: New product development essentials from the PDMA. John Wiley & Sons, 2015.
3. H. K. Versteeg and Malala Shekara, "Introduction to Finite Volume Method", Pearson, 2015 Pavan Soni, Design Your Thinking: The Mindsets, Toolsets and Skill Sets for Creative Problem-solving, Penguin Random House India Private Limited, 2020.
4. Pavan Soni, Design Your Thinking: The Mindsets, Toolsets and Skill Sets for Creative Problem-solving, Penguin Random House India Private Limited, 2020

Suggested Reading:

1. Jeanne Liedtka, Andrew King, Kevin Bennett, Solving problems with design thinking: Ten stories of what works. Columbia University Press, 2013.
2. Bala Ramadurai, Karmic Design Thinking - A Buddhism-Inspired Method to Help Create Human-Centered Products & Services, Edition 1, 2020.
3. Tom Kelley, David Kelley, Creative Confidence: Unleashing the Creative Potential Within Us All, Crown Business, 2013.
4. Michael Lewrick, Design Thinking and Innovation Metrics: Powerful Tools to Manage Creativity, OKRs, Product, and Business Success, Wiley, 2023.