Agnel Charities

Fr. C. Rodrigues Institute of Technology

Sector 9A, Vashi, Navi Mumbai, 400703, Maharashtra, India

www.fcrit.ac.in

An Autonomous Institute Affiliated to the University of Mumbai

Department of Mechanical Engineering

Curriculum Structure for

Honours/ Minors

Degree Programs in B. Tech

Approved By: Academic Council of Fr. C. Rodrigues Institute of Technology

Effective from :2025-26

Revision: 2024.1

PREAMBLE - DEAN ACADEMICS

Accelerating Towards Excellence: Unveiling a New Era in Education

Dear Students, Faculty, and Stakeholders,

It is with great pleasure and anticipation that we introduce the newly designed curriculum for autonomy at Agnel Charities' Fr. C. Rodrigues Institute of Technology. This pioneering initiative aims to revolutionize engineering education, ensuring our graduates are equipped with not only technical prowess but also the holistic skills necessary for thriving in today's dynamic professional landscape.

1. **Purpose of Autonomy:** Our commitment to autonomy is rooted in the imperative to bridge the gap between academia and industry. We envision education as a catalyst for individual growth, fostering self-sustainability and enhancing employability. Through our curriculum, we strive to nurture engineers who not only excel in their fields but also contribute meaningfully to society.

2. **Curriculum Design: A Top-to-Down Approach:** Our curriculum is meticulously crafted with a top-to-down approach, encompassing all 12 attributes of Program Outcomes mandated by regulatory bodies. Emphasizing a blend of theoretical knowledge and practical application, it is designed to cultivate well-rounded professionals capable of tackling real-world challenges with confidence and competence.

3. **Alignment with National Education Policy-2020:** In adherence to the guidelines laid out in the National Education Policy-2020, our curriculum embodies a multidisciplinary approach, offering a diverse array of core and elective courses. It integrates hands-on learning experiences such as mini and major projects, skill-based labs, and one-semester internships to nurture innovation and problem-solving skills. Additionally, the inclusion of value-added courses, honours, and minors ensures a comprehensive educational journey tailored to individual interests and aspirations.

4. **Opportunities for Teachers in Innovation:** We recognize the pivotal role of our faculty in shaping the educational experience. Our curriculum provides ample opportunities for teachers to innovate in teaching-learning methodologies and evaluation techniques. Through continuous professional development programs and collaborative platforms, we empower our educators to experiment with innovative pedagogies, leverage technology for enhanced learning outcomes, and implement novel assessment strategies. By fostering a culture of innovation among our faculty, we aim to enrich the learning experience and inspire a passion for lifelong learning among our students.

As we embark on this transformative journey, we invite all stakeholders to join us in shaping the future of engineering education. Together, let us strive towards excellence, innovation, and societal impact.

Sincerely,

Dean of Academics Agnel Charities' Fr. C. Rodrigues Institute of Technology

PREAMBLE - BOS CHAIRMAN

Dear Students and Stakeholders,

It is with great pleasure and anticipation that Board of Studies of Mechanical Engineering introduce the newly designed curriculum at Agnel Charities' Fr. C. Rodrigues Institute of Technology. We are committed to fostering a culture of innovation, excellence, and service in the field of mechanical engineering. As an autonomous institution, we embrace the responsibility of shaping the future of our profession and empowering our students to become proficient engineers, leaders, and global citizens.

Department has taken a lead in incorporating philosophy of outcome-based education in the process of curriculum development. Curriculum is aligned with Institute, Department vision and mission and with National Education Policy-2020. Program outcomes are based as per the guidelines mentioned in the NBA SAR-January 2016. Our department stands as a beacon of knowledge, dedicated to advancing the frontiers of mechanical engineering through cutting-edge research, interdisciplinary collaboration, and industry partnerships. We believe in the transformative power of education to inspire creativity, critical thinking, and ethical decision-making among our students.

Positioning of learning in real world is ensured to keep abreast of latest trends and technologies as per industry requirement. Well thought has been given to selection of courses while structuring the curriculum. Core courses, elective courses, Lab courses, skill-based lab courses and Honors/Minor verticals such as Electric Vehicle Technology, Supply Chain, 3D Printing, Data Science, Aeronautical Engineering are identified. Mechanical Engineering course integrates a range of experiential learning opportunities, including internships, mini and major projects, industry projects and collaborative research initiatives. Additionally, emphasis is placed on promoting a culture of lifelong learning, encouraging students to stay abreast of emerging trends, engage in continuous professional development, and contribute meaningfully to the advancement of the field.

Department has taken an initiative to design course syllabus by adapting leaner centered approach through backward design method facilitating the creation of more cohesive, clear and intentional learning experiences for learners. While designing the syllabus teacher has identified the desired results through setting the course and learning objectives aligned with Bloom's taxonomy and Performance Indicators. Teacher has identified the assessments that students will complete in order to demonstrate evidence of learning and even progress towards achievement of learning objectives. Based on this teacher has planned the contents. While planning the content points are considered as what enabling knowledge & skills will learner need in order to achieve desired results, what ways they will be evaluated along the way, what activities will equip learner with needed knowledge and skills, what will need to be taught and how should it best be done using pedagogical and innovative methods. The draft scheme and syllabus were presented to all stakeholders for receiving critical feedback and suggestions. Important and relevant suggestions were incorporated.

We invite all stakeholders to join us on this transformative educational journey, where students are empowered to become catalysts of innovation, drivers of change, and leaders of tomorrow's digital landscape. By embracing a holistic approach to learning, grounded in academic rigor, practical relevance, and ethical values, we strive to nurture a new generation of Mechanical Engineers poised to make a positive impact on society and shape a brighter future for generations to come.

Sincerely,
Chairman, Board of Studies – Mechanical Engineering,
Agnel Charities' Fr. C. Rodrigues Institute of Technology

Contents

A. Abbreviations

HMC	Honours or Minor Core Course
HML	Honours or Minor Laboratory
HMP	Honours or Minor Mini Project
RPR	Research Project
RPC	Research Project Coursework

Proposed Honours / Minor Degree specializations offered by Department of Mechanical Engineering are as follows.

Mapping as 'Honours' or 'Minor' Degree Program with Existing B. Tech Programs offered by the Department of Mechanical Engineering

<table>
<tr><th>Honours/Minor Specialization</th><th>B. Tech Program that can offer this as an Honours Degree</th><th>B. Tech Programs that can offer this as a Minor Degree</th></tr>
<tr><td>Data Analytics and AI</td><td rowspan="4">Mechanical Engineering</td><td rowspan="4">1. Computer Engineering
2. Electronics & Telecommunication Engineering
3. Electrical Engineering
4. Information Technology</td></tr>
<tr><td>Additive Manufacturing</td></tr>
<tr><td>Supply Chain</td></tr>
<tr><td>Aeronautical Engineering</td></tr>
</table>

Curriculum Structure for Honours/Minor Degree Program in 'Data Analytics and Artificial Intelligence'

Course Type	Sem	Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
				L	P	T	L	P	T	Total
HMC	V	HMCDA501	Artificial Intelligence and Machine Learning	3	--	--	3	--	--	3
HMC	VI	HMCDA602	Foundations of Data Science	3	--	--	3	--	--	3
HMC	VII	HMCDA703	Industrial Analytics	4	--	--	4	--	--	4
HML	VII	HMLDA701	Machine Learning Laboratory	--	4	--	--	2	--	2
HMC	VIII	HMCDA804	Deep Learning	4	--	--	4	--	--	4
HMP	VIII	HMPDA801	Mini Project	--	6	--	--	2	--	2
Total				**14**	**10**	**--**	**14**	**04**	**--**	**18**

Examination Scheme for Honours/Minor Degree Program in 'Data Analytics and Artificial Intelligence'

Course Type	Sem	Course Code	Course Name	In-Semester Assessment		End Sem Exam (ESE)	Exam duration for Theory (in Hrs)		
				Continuous Assessment	Mid Sem Exam		Mid Sem	End Sem	Total
HMC	V	HMCDA501	Artificial Intelligence and Machine Learning	20	30	50	1.5	2	100
HMC	VI	HMCDA602	Foundations of Data Science	20	30	50	1.5	2	100
HMC	VII	HMCDA703	Industrial Analytics	20	30	50	1.5	2	100
HML	VII	HMLDA701	Machine Learning Laboratory	50	--	--	--	--	50
HMC	VIII	HMCDA804	Deep Learning	20	30	50	1.5	2	100
HMP	VIII	HMPDA801	Mini Project	50	--	--	--	--	50
Total				**180**	**120**	**250**	**--**	**--**	**550**

Course Type	Course Code	Course Name	Credits
HMC	HMCDA703	INDUSTRIAL ANALYTICS	04

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. HMCDA501: Artificial Intelligence & Machine Learning
2. HMCDA602: Foundations of Data Science

Program Outcomes addressed :

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO3: Design/Development of solutions
4. PO4: Conduct Investigations of Complex Problems
5. PO5: Engineering Tool Usage
6. PO8: Individual and Team Work
7. PO11: Life-Long Learning

Course Objectives :

1. To analyze the role and impact of data analytics in industrial asset management and maintenance
2. To compare traditional maintenance and diagnostic approaches with machine learning–based predictive analytics
3. To explore emerging technologies and future trends in industrial asset analytics

Module	Details	Hrs
	Course Introduction Industrial Analytics focuses on applying data-driven methods to monitor, optimize, and predict industrial operations. It integrates sensors, IoT, and machine learning to extract actionable insights from manufacturing and process data. The course emphasizes real-time analytics, predictive maintenance, and performance optimization. Students learn to bridge engineering systems with data science for smarter, efficient, and sustainable industries.	**01**
01.	**Introduction to Industrial Analytics** ***Learning Objective/s:*** *To understand the principles, applications, and benefits of industrial analytics in mechanical engineering systems, emphasizing data-driven asset management,*	**5-7**

	maintenance optimization, and real-world implementation challenges and opportunities.	
	Contents:	
	Overview of Industrial Analytics, Importance and applications in mechanical engineering and industrial systems, Role of data analytics in asset management and maintenance, Challenges and opportunities in industrial asset analytics, Case studies and examples of successful implementations.	
	Self-Learning Topics: *Data Acquisition and Sensor Integration in Industrial Environments* ***Learning Outcomes :*** *A learner will be able to* *LO 1.1: Apply Mechanical engineering concepts to identify the problems related to the maintenance of the industrial systems. (P.I. 1.4.1)* *LO 1.2: Apply mathematical techniques such as calculus, linear algebra, and statistics for successful implementation of maintenance strategies. (P.I. 1.1.1)* *LO 1.3: Compare and contrast alternative analytics approaches, addressing limitations, risks, and data quality issues. (P.I. 2.2.4)* *LO 1.4: Identify system parameters, operational variables, and data sources relevant to mechanical engineering applications. (P.I. 2.1.2)* *LO 1.5: Recognize the need for industrial analytics in solving engineering problems related to asset performance and reliability. (P.I. 3.1.1)* *LO 1.6: Explore safety and risks issues in the maintenance of industrial assets.(P.I.3.1.5)*	
02.	**Fundamentals of Industrial Assets** ***Learning Objective/s:*** *To understand the types, hierarchy, and lifecycle of industrial assets, along with performance measurement and data acquisition methods using sensors, IoT, and SCADA systems.*	**9-11**
	Contents: Types of industrial assets: machinery, equipment, infrastructure, etc., Lifecycle of industrial assets: design, manufacturing, operation, maintenance, and decommissioning, Asset hierarchy and classification, Asset performance indicators and key performance indicators (KPIs), Data collection methods: sensors, IoT devices, SCADA systems, etc.	
	Self-Learning Topics:	
	Definition and classification of Machinery and rotating equipment assets	
	Learning Outcomes :	
	A learner will be able to *LO 2.1: Relate natural science principles like fatigue, wear, corrosion to failure causes uncovered through traditional analyses. (P.I. 1.2.1)* *LO 2.2: Apply mathematical tools to evaluate the industrial. performance. (P.I. 1.1.2)* *LO 2.3: Compare and contrast between different data collection methods like IoT devices and SCADA systems. (P.I. 2.1.2)* *LO 2.4: Break down complex system into failure modes, causes and their effects into structured sub-elements. (P.I. 2.2.1)*	

	LO 2.5: Use decision-making tools to prioritize critical assets based on FMEA scoring or RCM analysis. (P.I. 3.3.1) *LO 2.6: Develop an asset hierarchy and classification system to facilitate effective management and performance monitoring(P.I. 3.1.3)*	
03.	**Data Acquisition and Pre-processing**	**11-13**
	Learning Objective/s: *To understand and apply data collection, preprocessing, and time-series analysis techniques for reliable monitoring and integration of heterogeneous industrial data while effectively handling missing values and outliers.*	
	Contents: Data collection and storage in industrial environments, Data pre-processing techniques: cleaning, filtering, and normalization, Time-series data analysis for asset monitoring, Integration of heterogeneous data sources, Handling missing data and outliers.	
	Self-Learning Topics: *Use filtering methods (e.g., moving average, low-pass filters) to reduce sensor noise.* ***Learning Outcomes :*** *A learner will be able to* *LO 3.1: Apply normalization techniques to standardize data for effective analysis across different sources. (P.I. 1.1.1)* *LO 3.2: Compare various methods and technologies for data collection and storage specific to industrial environments. (P.I. 2.2.4)* *LO 3.3: Identify relevant system variables, measurement points, and parameters required for asset data collection.. (P.I. 2.1.2)* *LO 3.4: Identify suitable evaluation metric for evaluation of alternate design solutions. (P.I. 3.2.3)* *LO 3.5: Demonstrate skills in cleaning and filtering raw industrial data to remove noise and errors and evaluate the results by apply various visualization techniques to draw insights form that data in a team.. (P.I.1.2.1, 3.3.1,5.1.1, 5.1.2 ,8.2.1, 8.3.1)* *LO 3.6: Represent time-series data using appropriate visualization techniques to see the trends, moving averages and histograms. (P.I. 4.3.3)* *LO 3.7: Analyze processed data to determine the impact of missing data and corrected outliers.(P.I. 4.3.2)*	
04.	**Traditional vs. data driven / Machine Learning methods**	**9-11**
	Learning Objective/s: *To understand and compare traditional expert-based maintenance methods and modern machine learning approaches for reliability analysis and asset management.*	
	Contents:	
	Overview of traditional methods based on subject matter expert knowledge, such as: Reliability-centered maintenance (RCM), Failure modes and effects analysis (FMEA), Root cause analysis (RCA), Expert systems and rule-based approaches; Pros and cons; Comparison between traditional methods and ML-based methods; ML-based methods including: Regression for RUL, degradation model, Decision trees and random forests, Support vector machines (SVM) for condition monitoring, Unsupervised learning for anomaly detection,	

	Hybrid approaches: combining expert knowledge with machine learning algorithms, Case studies comparing the effectiveness of traditional methods and ML-based methods in asset management	
	Self-Learning Topics: *Understand the traditional approaches such as Failure rate, MTBF (Mean Time Between Failures) etc.*	
	Learning Outcomes :	
	A learner will be able to *LO 4.1: Apply regression, degradation modeling, and statistical learning techniques to predict Remaining Useful Life (RUL). (P.I. 1.1.1)* *LO 4.2: Apply natural science and engineering principles to understand failure mechanisms addressed in traditional methods. (P.I. 1.2.1)* *LO 4.3: Compare alternative solution methods like expert-based vs ML-based methods and select the best for a given problem. (P.I. 2.2.4)* *LO 4.4: Identify ML models like decision trees, random forests, SVMs for condition monitoring and failure prediction. (P.I. 2.1.3)* *LO 4.5: Compare hybrid and standalone approaches to select the optimal solution for specific asset health scenarios.(P.I.3.3.1)* *LO 4.6: Derive functional requirements and specifications based on the outcomes of RCM/FMEA/RCA.(P.I. 3.1.6)*	
05.	**Predictive Maintenance and Failure Prediction** ***Learning Objectives:*** *To understand and apply predictive maintenance and condition-based maintenance concepts using predictive analytics, reliability analysis, and prognostics techniques for effective asset health management and maintenance optimization.*	**9-11**
	Contents:	
	Concepts of predictive maintenance (PdM) and condition-based maintenance (CBM), Predictive analytics techniques for failure prediction, Prognostics and health management (PHM) of industrial assets, Reliability analysis and reliability-centered maintenance (RCM), Case studies on successful implementation of predictive maintenance strategies	
	Self-Learning Topics: *Physical data acquisition from machinery like FFT analysis, mis-alignment detection* ***Learning Outcomes :***	
	A learner will be able to *LO 5.1: Apply statistical, machine-learning, and advanced mathematical techniques to model failure patterns.. (P.I. 1.1.1,5.1.1,5.1.2)* *LO 5.2: Apply mechanical engineering concepts to understand degradation behavior and Remaining Useful Life (RUL) calculations. (P.I. 1.4.1)* *LO 5.3: Break down complex health assessment problems into subproblems such as fault detection, diagnosis and prognosis. (P.I. 2.2.1)* *LO 5.4: Compare and contrast with different maintenance strategies, selecting the optimal RCM methodology. (P.I. 2.2.4)* *LO5.5: Analyze case study data, synthesize information, and draw conclusions regarding PdM effectiveness.(P.I. 4.3.1)* *LO5.6: Analyze sensor data trends to identify early warning indicators of equipment failure.(P.I.4.3.2)*	
06.	**Advanced Topics in Industrial Asset Analytics**	**9-11**

	Learning Objective/s: *To understand and apply advanced concepts of big data analytics, digital twins, and cyber-physical systems for intelligent monitoring, modeling, and optimization of industrial assets in the context of Industry 4.0.*	
	Contents:	
	Big data analytics for industrial assets, Digital twins and virtual asset modeling, Cyber-physical systems (CPS) and Industry 4.0 applications, Emerging trends and future directions in industrial asset analytics.	
	Self-Learning Topics: *Time-series data processing and anomaly detection*	
	Learning Outcomes : *A learner will be able to* *LO 6.1: Define asset-related problems using large datasets, identify important variables, and establish analysis objectives. (P.I.2.1.1)* *LO 6.2: Compare and contrast the alternative architectures like edge computing vs cloud; fieldbus vs OPC-UA (P.I. 2.2.4)* *LO 6.3: Review state-of-the-art technologies such as AI-enabled maintenance, AR/VR, 5G, blockchain and CPS. (P.I. 3.1.3)* *LO 6.4: Select optimal emerging technologies for industrial systems. (P.I. 3.3.1)* *LO 6.5: Establish relationship between the digital twin and virtual asset model. (P.I. 4.1.4)* *LO6.6: Identify deficiencies or gaps in Industry 4.0 and demonstrate an ability to source information to close this gap in a team.(P.I.4.3.4 , 8.2.1,8.3.1,11.1.2,11.2.2)*	
	Course Conclusion	**01**
	Total	**60**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems
1.1.2	Apply advanced mathematical techniques to model and solve mechanical engineering problems
1.2.1	Apply laws of natural science to an engineering problem.
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.1	Articulate problem statements and identify objectives
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
2.2.1	Reframe complex problems into interconnected sub-problems.
2.2.4	Compare and contrast alternative solution processes to select the best process.
3.1.1	Recognize that need analysis is key to good problem definition

3.1.3 Synthesize engineering requirements from a review of the state-of-the-art

3.1.5 Explore and synthesize engineering requirements considering health, safety risks, environmental, cultural and societal issues.

3.1.6 Determine design objectives, functional requirements and arrive at specifications

3.2.3 Identify suitable criteria for evaluation of alternate design solutions

3.3.1 Apply formal decision making tools to select optimal engineering design solutions for further development

4.1.4 Establish a relationship between measured data and underlying physical principles.

4.3.1 Use appropriate procedures, tools and techniques to conduct experiments and collect data

4.3.2 Analyze data for trends and correlations, stating possible errors and limitations

4.3.3 Represent data (in tabular and/or graphical forms) so as to facilitate analysis and explanation of the data, and drawing of conclusions

4.3.4 Synthesize information and knowledge about the problem from the raw data to reach appropriate conclusions

5.1.1 Identify modern engineering tools such as computer aided drafting, modeling and analysis; techniques and resources for engineering activities

5.1.2 Create/adapt/modify/extend tools and techniques to solve engineering problems

8.2.1 Demonstrate effective communication, problem solving, conflict resolution and leadership skills

8.3.1 Present results as a team, with smooth integration of contributions from all individual efforts

11.1.2 Identify deficiencies or gaps in knowledge and demonstrate an ability to source information to close this gap

11.2.2 Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field

Course Outcomes : Learner will be able to

1. Identify the role of data analytics in asset management and maintenance. (*LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5, LO 1.6*)
2. Identify the industrial assests and key performance parameters to asses the asset lifecycle. (*LO 2.1, LO 2.2, LO 2.3, LO 2.4 , LO 2.5, LO 2.6*)
3. Apply the statistical techniques to collect and analyse the data to solve engineering problems. (*LO 3.1, LO 3.2, LO 3.3, LO 3.4 , LO 3.5, LO 3.6, LO 3.7*)
4. Apply Machine learning techniques to develop ML models for condition monitoring and failure prediction .(*LO 4.1, LO 4.2, LO 4.3, LO 4.4 , LO 4.5, LO 4.6*)
5. Apply statistical and machine-learning techniques to model failure patterns. (*LO 5.1, LO 5.2, LO 5.3, LO 5.4 , LO 5.5, LO 5.6*)
6. Analyze the models by establishing the relationship between the digital twin and virtual asset model. (*LO 6.1, LO 6.2, LO 6.3, LO 6.4 , LO 6.5, LO 6.6*)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCDA703.1	3	3	3	--	--	--	--	--	--	--	--
HMCDA703.2	3	3	3	--	--	--	--	--	--	--	--
HMCDA703.3	3	3	3	3	3	--	--	3	--	--	--
HMCDA703.4	3	3	3	--	--	--	--	--	--	--	--
HMCDA703.5	3	3	--	3	3	--	--	--	--	--	--
HMCDA703.6	--	3	3	3	--	--	--	3	--	--	3
Average	**3**	**3**	**3**	**3**	**3**	**--**	**--**	**3**	**--**	**--**	**3**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Industrial Data Analytics for Diagnosis and Prognosis: A Random Effects Modelling Approach , Shiyu Zhou & Yong Chen , 1st edition , 2022 , Wiley-Blackwell.
2. Value Based and Intelligent Asset Management: Mastering the Asset Management Transformation in Industrial Plants and Infrastructures , Adolfo Crespo Márquez, Marco Macchi, Ajith Kumar Parlikad (eds.) , 1st edition , 2020 , Springer
3. Guide to Industrial Analytics: Solving Data Science Problems for Manufacturing and the Internet of Things , Richard Hill, Stuart Berry , 1st edition , 2021 , Springer
4. System Reliability Theory: Models, Statistical Methods, and Applications , Marvin Rausand, Arnljot Høyland , 2nd edition , 2004 , Wiley
5. Machine Learning for Predictive Maintenance , Davide Manca, Diego Gallo , 1st edition , 2022 , Springer
6. Condition-Based Maintenance and Machine Diagnostics , John D. Campbell , 1st Edition , 2018 , CRC Press.
7. Big Data: Principles and Best Practices of Scalable Realtime Data Systems , Nathan Marz, James Warren , 1st Edition , 2015 , Manning
8. Digital Twin: Concepts and Applications in Manufacturing Systems , Suranga Nanayakkara , 1st Edition , 2022 , CRC Press
9. Cyber-Physical Systems: From Theory to Practice , Rajkumar Buyya, Satish Narayana Srirama , 1st Edition , 2022 , Springer
10. Industry 4.0: Managing the Digital Transformation , Alp Ustundag, Emre Cevikcan , 1st Edition , 2018 , Springer

Reference Books :

1. Data Analytics and Artificial Intelligence for Predictive Maintenance in Smart Manufacturing , Amit Kumar Tyagi, Shrikant Tiwari, Gulshan Soni , 1st edition , 2024 , Taylor & Francis

2. Intelligent Condition Monitoring and Diagnosis Systems , Jongdae Kim , 1st edition , 2020 , Springer
3. Predictive Maintenance in Smart Factories , Davide Gallo, Ivan Zoratti , 1st edition , 2021 , Springer
4. Cyber-Physical Systems: A Computing Perspective , 1st Edition , 2021 , Morgan & Claypool

Other Resources :

1. NPTEL Course: Introduction to Industry 4.0 and Industrial internet of things By Prof. Sudeep Misra, Department of Computer Science and Engineering, IIT Kharagpur :-Web link- Introduction to Industry 4.0 and Industrial Internet of Things - Course
2. NPTEL Course: Machinery Fault Diagnosis And Signal Processing By Prof. A.R.Mohanty, Department of Management , IIT Kharagpur :-
   Web link-nptel.ac.in/courses/112105232

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

Two Class tests	:	10 Marks
Flip classroom	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination carrying 20% weightage, and the syllabus covered from MSE to ESE carrying 80% weightage

Course Type	Course Code	Course Name	Credits
HML	HMLDA701	MACHINE LEARNING LABORATORY	02

Examination Scheme		
Continuous Assessment	**End Semester Exam (ESE)**	**Total**
50	--	50

Pre-requisite :

1. HMCDA501 - Artificial Intelligence and Machine Learning
2. HMCDA602 - Foundations of Data Science
3. HMCDA703 - Industrial Analytics

Program Outcomes addressed :

1 PO1: Engineering Knowledge
2 PO2: Problem Analysis
3 PO4: Conduct Investigations of Complex Problems
4 PO5: Engineering Tool Usage
5 PO8: Individual and Collaborative Team work
6 PO9: Communication

Course Objectives:

1. To get acquainted with Python and essential libraries such as Pandas, NumPy, Matplotlib for basic data analysis tasks.
2. To develop the skills such as data acquisition , data pre-processing and evaluation techniques to assess the performance of industrial assets using Machine Learning methods.
3. To get acquainted with traditional and data driven methods to build predictive maintenance models
4. To develop the digital twins model which can be used for predictive maintenance and performance optimization.

Module	Detailed Contents	Hrs
	The **Machine Learning Laboratory for Industrial Analytics** introduces students to data-driven techniques used for monitoring and improving industrial asset performance. Through hands-on exercises with Python tools and real industrial datasets, students learn how to preprocess data, calculate key asset performance indicators, and apply both traditional engineering methods and modern machine learning algorithms. The course also explores predictive maintenance, failure prediction models, and digital twin concepts, preparing students to work with advanced analytics tools used in Industry 4.0 environments.	**01**
01.	**Introduction to Data Analytics Tools**	**07**

	Learning Objective/s: *To explore Python libraries like Pandas, NumPy, and Matplotlib to analyze, visualize, and interpret sample datasets related to mechanical engineering or industrial systems.*	
	Contents: Introduction to Data Analytics Tools like Python or MATLAB , Python libraries like Pandas , Numpy , Matplotlib and Scikit-learn for data Analysis	
	Experiment / s : 1. **Performing Basic Data Exploration (Using NumPy, Pandas and Matplotlib):** Analyze a dataset (CSV file) using NumPy and Pandas. Calculate statistics, visualize data using Matplotlib, and draw insights from the analysis. 2. **Application of Machine Learning models using Scikit-Learn :** Build a classification model / regression model for the dataset using Sci-kit learn library in python.	
	Self-Learning Topics: *Fundamentals of Python programming and MATLAB software.*	
	Learning Outcomes : *A learner will be able to* *LO 1.1:* Apply basic mathematical and statistical principles to analyze a dataset, define the data analysis problem and extract meaningful insights using modern data analysis tools such as NumPy, Pandas, and Matplotlib while validating the credibility of results. *(PI:1.1.1, 2.1.2, 2.4.4, 5.1.2)* *LO1.2:* Design and implement a suitable machine learning model using modern tools and justify the solution based on performance criteria *(PI:1.3.1 , 3.2.2 , 3.2.3 , 5.1.1)*	
02.	**Data Preprocessing Techniques and Asset Performance Indicators (KPIs) Calculation** ***Learning Objective/s:*** *To pre-process the data and calculate key performance indicators (KPIs) from industrial asset datasets and interpret their significance in evaluating asset health and performance.*	**12**
	Contents: Handling missing data and outliers Calculation of key performance indicators for given industrial asset datasets, Understand the significance of different KPIs in assessing asset performance.	
	Experiment / s : 3. **Pre-processing of data:** To implement data cleaning, filtering, and normalization techniques on real industrial data to handle missing values and outliers in the dataset. 4. **Calculation of key performance indicators:** To analyze industrial asset performance by calculating and interpreting key performance indicators such as Availability, Utilization, Performance Efficiency, Quality Rate, Overall Equipment Effectiveness (OEE), Reliability, and Maintenance Cost using real industrial asset datasets.	
	Self-Learning Topics:	

	Learning Outcomes: *A learner will be able to* *LO 2.1: Apply statistical techniques and modern engineering tools to clean, normalize, and preprocess data, and extract meaningful insights while considering analysis limitations. (PI: 1.1.1, 2.2.3, 2.4.4, 5.2.2)* *LO 2.2: Apply advanced mathematical techniques to calculate KPI's for industrial asset problems and analyze data for trends and correlations by representing data in tabular and/or graphical forms so as to draw the conclusions (PI: 1.1.2, 4.3.2, 4.3.3, 5.1.2)*	
03	**Predictive Maintenance and Failure Prediction using traditional and data-driven methods.** ***Learning Objective/s:*** *To explore traditional reliability methods and familiarize with machine learning techniques to develop and evaluate predictive maintenance models for industrial assets.*	**20**
	Contents: Implementation of traditional methods like RCM, FMEA, and RCA on sample industrial asset problems and comparing the results with ML-based methods like regression, decision trees, and SVM. Build predictive maintenance models using machine learning algorithms on historical asset data and evaluate the effectiveness of different predictive analytics techniques for failure prediction.	
	Experiment / s : **5. Compare the traditional and ML based methods :** To compare the results of industrial assests insights using the traditional and ML-based methods. **6. Predictive maintenance :** To apply machine learning algorithms to build a predictive maintenance model for failure prediction. **7. Comparison of Predictive maintenance model :** To compare the effectiveness of predictive maintenece model for failure prediction.	
	Self-Learning Topics: ---	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Compare traditional and ML-based methods using modern tools and extract desired understanding and conclusions consistent with objectives and limitations of the analysis (P.I. 2.2.4 , 2.4.4 , 5.1.2)* *LO 3.2: analyze data for trends and correlations between the failure patterns using modern tools and presenting data in tabular and/or graphical forms so as to draw the conclusions in a team.(P.I. 4.3.2 , 4.3.3 , 5.2.2 , 8.1.2 , 8.2.1 , 9.1.3 , 9.3.1)*	
04.	**Digital Twins and Virtual Asset Modeling** ***Learning Objective/s:*** *To familiarize with the development of digital twins or virtual models of industrial assets using simulation software.*	**20**

	Contents: Development of digital twins or virtual models of industrial assets using simulation software	
	Experiment / s : **8. Digital Twins and Virtual Asset Modeling :** To develop digital twins or virtual models of industrial assets using simulation software.	
	Self-Learning Topics: ---	
	Learning Outcomes : *A learner will be able to* *LO 3.1: develop digital twins or virtual models of industrial assets using simulation software, apply engineering principles for modeling, and validate model accuracy against real-world data (P.I. 2.3.1, 2.4.2, 5.1.2, 5.2.2)*	
	Total	**60**

Performance Indicators:

P.I. No.	P.I. Statement
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems.
1.1.2	Apply advanced mathematical techniques to model and solve mechanical engineering problems.
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
2.1.1	Articulate problem statements and identify objectives
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions.
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.4.2	Produce and validate results through skilful use of contemporary engineering tools and models.
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis
3.1.1	Recognize that need analysis is key to good problem definition
3.1.2	Elicit and document, engineering requirements from stakeholders
4.3.2	Analyze data for trends and correlations, stating possible errors and limitations
4.3.3	Represent data (in tabular and/or graphical forms) so as to facilitate analysis and explanation of the data, and drawing of conclusions
5.1.1	Identify modern engineering tools such as computer aided drafting, modeling and analysis; techniques and resources for engineering activities
5.1.2	Create/adapt/modify/extend tools and techniques to solve engineering problems
5.2.2	Demonstrate proficiency in using discipline specific tools.
8.1.2	Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.

8.2.1 Demonstrate effective communication, problem solving, conflict resolution and leadership skills.

9.1.3 Create flow in a document or presentation - a logical progression of ideas so that the main point is clear

9.3.1 Create engineering-standard figures, reports and drawings to complement writing and presentations

Course Outcomes: A learner will be able to

1. Analyze datasets using Python libraries such as NumPy, Pandas, and Matplotlib to extract insights, and apply machine learning models with Scikit-Learn for classification and regression tasks. *(LO 1.1, LO 1.2)*
2. Apply data pre-processing techniques such as cleaning, filtering, and normalization to industrial datasets, and analyze asset performance by calculating and interpreting key performance indicators including Availability, Utilization, OEE, Reliability, and Maintenance Cost. *(LO 2.1, LO 2.2)*
3. Analyze and compare traditional asset analysis methods with machine learning–based approaches, and develop, evaluate, and compare predictive maintenance models for effective failure prediction. *(LO 3.1 , LO 3.2)*
4. Develop digital twins or virtual models of industrial assets using simulation software for performance analysis and decision support. *(LO 4.1)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMLDA701.1	3	3	3	--	3	--	--	--	--	--	--
HMLDA701.2	3	3	--	3	3	--	--	--	--	--	--
HMLDA701.3	--	3	--	3	3	--	--	3	3	--	--
HMLDA701.4	--	3	--	--	3	--	--	--	--	--	--
Average	3	**3**	**3**	**3**	**3**	**--**	**--**	**3**	**3**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Books :

1. "Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow" , Aurélien Géron , 2nd Edition , 2019 , O'Reilly Media
2. "Python for Data Analysis", Wes McKinney , 2nd Edition , 2017 , O'Reilly Media
3. "Reliability-Centered Maintenance" , John Moubray , 2nd Edition , 1997 , Butterworth-Heinemann
4. "Practical Predictive Maintenance of Industrial Systems" , Tsuyoshi Ohtomo, Tetsuya Higuchi , 1st Edition , 2020 , Wiley
5. "Digital Twin Driven Smart Manufacturing" , Fei Tao, Qinglin Qi, Ang Liu , 1st Edition , 2019 , Elsevier / Academic Press

Reference Books :

1. "Asset Management Excellence" , John D. Campbell , 1st Edition , 2016 , CRC Press
2. "Machine Learning for Asset Managers" , Marcos López de Prado , 1st Edition , 2020 , Cambridge University Press

3. “Practical Statistics for Data Scientists” , Peter Bruce, Andrew Bruce, Peter Gedeck , 2nd Edition , 2020 , O’Reilly Media

Other Resources :

1. “Industry 4.0: Managing The Digital Transformation, IIT Bombay”, Prof. Murli Dhar Agarwal , Department of Management Science and Research , IIT Bombay

   WebLink :- nptel.ac.in/courses/127101872

2. “Machine Learning for Core Engineering Disciplines” , Prof. Ananth Govind Rajan, Department of Chemical Engineering , IISC Banglore

   Web link :- https://onlinecourses.nptel.ac.in/noc25_ge77/preview

IN-SEMESTER ASSESSMENT (50 MARKS)

Continuous Assessment (50 Marks)

Performance based on completion of task (Marks will be awarded to students based on task performance with proper understanding)	:	20
Oral based on tasks	:	10
Case Study Presentation (max 4 students)	:	15
Regularity and Active Participation	:	05

Course Type	Course Code	Course Name	Credits
HMC	HMCDA804	DEEP LEARNING	04

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. HMCDA703: Industrial Analytics

Program Outcomes addressed :

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO3: Design/Development of solutions
4. PO4: Conduct Investigations of Complex Problems
5. PO5: Engineering Tool Usage
6. PO8: Individual and Collaborative Team Work

Course Objectives :

1. To familiarize with the foundational concepts and architectures of neural networks and deep learning models.
2. To explore deep learning techniques to solve real-world problems across domains.
3. To get acquainted with advanced deep learning concepts and emerging trends in deep learning.

Module	Details	Hrs.
	Course Introduction Neural networks are brain-inspired computational systems made up of layered perceptrons that can learn and extract complex patterns from data. With the advancement of deep learning, deeper architectures and training algorithms like backpropagation and gradient descent have enhanced their learning efficiency and accuracy. Today, these models play a crucial role in diverse domains such as image and speech analysis, language processing, robotics, and healthcare, contributing significantly to modern artificial intelligence.	**01**
01.	**Introduction to Deep Learning** ***Learning Objective/s:*** *To get acquainted with the basic architecture and training principles of neural networks and their key applications across various domains.*	**5-7**
	Contents:	

	Overview of Neural Networks, History and evolution of Deep Learning, Importance and applications in various fields, Basic architecture of neural networks: Perceptron's, Activation functions, Layers, Training process: Backpropagation, Gradient Descent.	
	Self-Learning Topics: --- ***Learning Outcomes :*** *A learner will be able to* *LO 1.1: Apply the natural science and computational principles to calculate weights for neural computation. (P.I. 1.2.1)* *LO 1.2: Apply calculus-based differentiation and chain rule concepts to compute gradients in backpropagation. (P.I. 1.1.2)* *LO 1.3: Formulate neural network models by defining perceptrons, weights, biases, activation functions, and layer structures.. (P.I. 2.3.1)* *LO 1.4: Compare earlier shallow models with modern deep architectures and justify their performance differences. (P.I. 2.2.4)*	
02.	**Convolutions Neural Networks (CNNs)** ***Learning Objective/s:*** *To get familiarize with CNN architectures for image analysis and transfer learning in computer vision tasks.*	**9-11**
	Contents: Introduction to CNNs, Architecture of CNNs: Convolutional layers, pooling layers, Fully connected layers, Applications of CNNs: Image classification, Object detection, Image segmentation, Transfer learning with pre-trained CNNs Case studies and examples of CNN applications.	
	Self-Learning Topics:	

	Learning Outcomes :	
	A learner will be able to *LO 2.1: Apply mathematical techniques to compute feature maps, convolution operations, and pooling outputs. (P.I. 1.1.1)* *LO 2.2: Apply natural science and computational principles for pattern recognition and signal filtering in convolution operations. (P.I. 1.2.1)* *LO 2.3: Identify design assumptions and constraints like kernel size, stride and padding, which is essential for CNN performance. (P.I. 2.3.2)* *LO 2.4: Extract meaningful insights from CNN output visualizations such as feature maps, bounding boxes and segmentation masks) (P.I. 2.4.4)* *LO 2.5: Select optimal CNN applications for classification, detection and segmentation tasks for corresponding industrial or engineering use-cases. (P.I. 3.3.1)* *LO 2.6: Identify suitable criteria for evaluation of different CNN models.. (P.I. 3.2.3)*	
03.	**Recurrent Neural Networks (RNNs)**	**11-13**
	Learning Objective/s: *To explore RNN architectures (Basic, LSTM, GRU) for sequential data tasks such as language modeling and time-series analysis, addressing key training challenges.*	

	Contents: Introduction to RNNs, Architecture of RNNs: Basic RNNs, Long Short-Term Memory (LSTM), Gated Recurrent Unit (GRU), Applications of RNNs: Sequence prediction, Language modelling, Time-series analysis, Training challenges: Vanishing and exploding gradients, Case studies and examples of RNN applications.	
	Self-Learning Topics: *Implementation and analysis of LSTM Network for Time-Series Forecasting.* ***Learning Outcomes :*** *A learner will be able to* *LO 3.1: Apply engineering and mathematical principles to understand sequential data processing in RNNs. (P.I. 1.4.1)* *LO 3.2: Apply mathematical operations to compute hidden state updates, gate activations, and output sequences. (P.I. 1.1.1)* *LO 3.3: Formulate RNN architectures by defining recurrent connections, hidden states, and update rules for basic RNNs, LSTMs, and GRUs. (P.I. 2.3.1)* *LO 3.4: Evaluate resources (data, tools, computational frameworks) required for sequence prediction and time-series tasks. (P.I. 2.2.2)* *LO 3.5: Select appropriate RNN architectures (Basic RNN, LSTM, GRU) for specific sequence-based problems. (P.I. 3.3.1)* *LO 3.6: Identify suitable criteria for evaluation of different CNN models.. (P.I. 3.2.3)* *LO 3.7: Examine sequential data trends, prediction errors, and model performance by representing outputs such as probability distributions and prediction curves graphically using appropriate tools to analyze real-world case studies involving RNN deployment in a team. (P.I.4.3.2 , 4.3.3 , 5.1.1 , 5.1.2 , 8.2.1 , 8.3.1)*	
04.	**Generative Adversarial Networks (GANs)** ***Learning Objective/s:*** *To get acquainted with GANs architecture and working principles, including the generator, discriminator, and adversarial training process, and to analyze their applications and limitations in image generation, style transfer, and data augmentation.*	**9-11**
	Contents: Introduction to GANs, Architecture of GANs: Generator, Discriminator, Training process: Adversarial training, Minimax game, Applications of GANs: Image generation, Style transfer, Data augmentation, Challenges and limitations of GANs.	
	Self-Learning Topics: --- ***Learning Outcomes :*** *A learner will be able to* *LO 4.1: Apply calculus and gradient-based reasoning to understand the minimax objective and loss functions.. (P.I. 1.1.2)* *LO 4.2: Apply mathematical operations used in generator and discriminator computations to transform and convolute data. (P.I. 1.1.1)* *LO 4.3: Formulate GAN architecture including generator networks, discriminator networks, and latent input spaces. (P.I. 2.3.1)*	

	LO 4.4: Validate GAN output using metrics such as FID, IS, or qualitative visual assessment. (P.I. 2.4.2) *LO 4.5: Examine tools and techniques used for stabilizing GAN training such as label smoothing and architectural adjustments) (P.I. 4.1.2)* *LO 4.6: Represent generated images and transformations effectively to facilitate interpretation of GAN outputs. (P.I. 4.3.3)*	
05.	**Deep Reinforcement Learning** ***Learning Objectives:*** *To get familiarized with the core concepts and algorithms of reinforcement learning, including deep Q-learning and policy gradient methods, for developing autonomous decision-making systems.*	**9-11**
	Introduction to Reinforcement Learning (RL), Basics of Deep Q-Learning (DQN), Policy gradients methods: Actor-Critic algorithms, Applications of Deep RL: Game playing, Robotics, Autonomous systems, Challenges in Deep RL: Exploration vs. Exploitation, Reward shaping.	
	Self-Learning Topics: --- ***Learning Outcomes :*** *A learner will be able to* *LO 5.1: Apply mathematical operations for Q-value updates, Bellman equations, and temporal-difference learning.(P.I. 1.1.1)* *LO 5.2: Apply calculus such as log-derivative trick and gradient estimation in policy gradient computation.(P.I. 1.1.2)* *LO 5.3: Apply gradient-based optimization techniques to update actor and critic components. (P.I. 2.4.1)* *LO 5.4: Extract insights and conclusions from performance metrics such as reward curves, success rates, and convergence trends.. (P.I. 2.4.4)* *LO 5.5: Represent RL results using graphical visualization such as learning curves, trajectories and policy outputs (P.I. 4.3.3)* *LO 5.6: Investigate the importance of reinforcement Learning in Artificial Intelligence. (P.I. 4.1.1)*	
06.	**Advanced Topics in Deep Learning** ***Learning Objective/s:*** *To explore advanced concepts in deep learning such as attention mechanisms, transformers, meta-learning, few-shot learning, and explainable AI for developing adaptive and interpretable models.*	**9-11**
	Contents:	
	Attention mechanisms in Deep Learning, Transformers and Self-Attention, Meta-learning and Few-shot Learning, Explainable AI and Interpretability in Deep Learning models, Emerging trends and future directions in Deep Learning.	
	Self-Learning Topics: --- ***Learning Outcomes :*** *A learner will be able to*	

	LO 6.1: Apply mathematical operations to compute self-attention scores and normalization steps. (P.I. 1.1.1) *LO 6.2: Apply engineering and mathematical concepts to understand model adaptation with minimal data. (P.I. 1.4.1)* *LO 6.3: Extract insights using interpretability tools such as SHAP, LIME and saliency maps (P.I. 2.4.4)* *LO 6.4: Compare emerging methods (efficient transformers, multimodal models, diffusion models) to existing approaches. (P.I. 2.2.4)* *LO 6.5: Synthesize recent advancements in deep learning (e.g., diffusion models, multimodal transformers, efficient architectures). (P.I. 3.1.3)* *LO 6.6: Evaluate ethical, safety, and societal implications of non-transparent deep learning systems. (P.I. 3.1.5)*	
	Course Conclusion	**01**
	Total	**60**

Performance Indicators:

P.I. No.	P.I. Statement
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems
1.1.2	Apply advanced mathematical techniques to model and solve mechanical engineering problems
1.2.1	Apply laws of natural science to an engineering problem
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.2.2	Identify, assemble and evaluate information and resources.
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.3.2	Identify assumptions (mathematical and physical) necessary to allow modeling of a system at the level of accuracy required.
2.4.1	Apply engineering mathematics and computations to solve mathematical models
2.4.2	Produce and validate results through skilful use of contemporary engineering tools and models
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis
3.1.3	Synthesize engineering requirements from a review of the state-of-the-art
3.1.5	Explore and synthesize engineering requirements considering health, safety risks, environmental, cultural and societal issues
3.2.3	Identify suitable criteria for evaluation of alternate design solutions.
3.3.1	Apply formal decision making tools to select optimal engineering design solutions for further development
4.1.1	Define a problem, its scope and importance for purposes of investigation
4.1.2	Examine the relevant methods, tools and techniques of experiment design, system calibration, data acquisition, analysis and presentation

4.3.2 Analyze data for trends and correlations, stating possible errors and limitations

4.3.3 Represent data (in tabular and/or graphical forms) so as to facilitate analysis and explanation of the data, and drawing of conclusions

5.1.1 Identify modern engineering tools such as computer aided drafting, modeling and analysis; techniques and resources for engineering activities

5.1.2 Create/adapt/modify/extend tools and techniques to solve engineering problems

8.2.1 Demonstrate effective communication, problem solving, conflict resolution and leadership skills

8.3.1 Present results as a team, with smooth integration of contributions from all individual efforts

Course Outcomes : Learner will be able to -

1. Apply the basic principles of neural network architecture and training to construct simple deep learning models. (*LO 1.1, LO 1.2, LO 1.3, LO 1.4*)
2. Demonstrate the CNN architectures for computer vision tasks such as image classification, object detection, and image segmentation. (*LO 2.1, LO 2.2, LO 2.3, LO 2.4 , LO 2.5, LO 2.6*)
3. Develop the RNN-based models to sequence-related tasks such as sequence prediction, language modelling, and time-series analysis. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4 , LO 3.5, LO 3.6,LO 3.7)*
4. Demonstrate the GAN training process for practical tasks such as image generation, style transfer, and data augmentation. *(LO 4.1, LO 4.2, LO 4.3, LO 4.4 , LO 4.5, LO 4.6)*
5. Apply RL and Deep RL algorithms to practical domains such as game playing, robotics, and autonomous systems. *(LO 5.1, LO 5.2, LO 5.3, LO 5.4 , LO 5.5, LO 5.6)*
6. Analyze key methods for explainability and interpretability in deep learning models and evaluate their importance in trustworthy and transparent AI systems. *(LO 6.1, LO 6.2, LO 6.3, LO 6.4 , LO 6.5, LO 6.6)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCDA804.1	3	3	--	--	--	--	--	--	--	--	--
HMCDA804.2	3	3	3	--	--	--	--	--	--	--	--
HMCDA804.3	3	3	3	3	3	--	--	3	--	--	--
HMCDA804.4	3	3	--	3	--	--	--	--	--	--	--
HMCDA804.5	3	3	--	3	--	--	--	--	--	--	--
HMCDA804.6	3	3	3	--	--	--	--	--	--	--	--
Average	**3**	**3**	**3**	**3**	**3**	**--**	**--**	**3**	**--**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. "Deep Learning" , Ian Goodfellow, Yoshua Bengio, Aaron Courville , 1st Edition , 2016 , MIT

Press

2. Reinforcement Learning: An Introduction , Richard S. Sutton, Andrew G. Barto , 2nd Edition , 2018 , MIT Press
3. Natural Language Processing with Transformers , Lewis Tunstall, Leandro von Werra, Thomas Wolf , 1st Edition , 2022 , O'Reilly Media

Reference Books :

1. Neural Networks and Deep Learning , Michael A. Nielsen , Online/Print Edition , 2015 , Determination Press
2. Generative Adversarial Networks (GANs): Algorithms, Applications, and Theory , Jakub Langr, Vladimir Bok , 1st Edition , 2019 , Packt Publishing
3. Pattern Recognition and Machine Learning , Christopher M. Bishop , 1st Edition , 2006 , Springer

Other Resources :

1. NPTEL Course: Deep Learning By Prof. Prabir Kumar Biswas, Department of Electronics and Electrical Communication Engineering, IIT Kharagpur :-Web link- https://onlinecourses.nptel.ac.in/noc20_cs62/preview
2. NPTEL Course: Deep Learning For Computer Vision by Prof. Vineeth N Balasubramanian, Department of Computer Science and Engineering , IIT Hyderabad :-
Web link- nptel.ac.in/courses/106106224

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

Two class Tests	:	10 Marks
Flip classroom	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination carrying 20% weightage, and the syllabus covered from MSE to ESE carrying 80% weightage

Course Type	Course Code	Course Name	Credits
HMP	**HMPDA801**	**Honours/Minor Mini Project**	**02**

Program Outcomes addressed:

1. **PO1 : Engineering knowledge**
2. **PO2 : Problem Analysis**
3. **PO3 : Design/Development of Solutions**
4. **PO4 : Conduct investigations of complex problems**
5. **PO5 : Modern Tool Usage**
6. **PO6 : The Engineer & World**
7. **PO7 : Ethics**
8. **PO8 : Individual & team work**
9. **PO9 : Communication**
10. **PO10: Project Management & Finance**
11. **PO11: Life-long learning**

Course Objectives

1. To guide students in identifying specialization-domain problems
2.. To explore advanced solutions using emerging technologies and specialized tools.
3. To develop research aptitude, innovation mindset, entrepreneurship potential, and lifelong learning skills.
4.. To foster self-directed learning, domain-specific competency, and collaboration.

Course Outcomes

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

CO1: Identify and articulate a domain-relevant societal, industrial, or research problem using literature review and analysis.

CO2: Apply engineering principles and specialized tools to design innovative and feasible technical solutions.

CO3: Conduct investigations, simulations, or experiments to validate the proposed solution using appropriate methods.

CO4: Evaluate the solution considering sustainability, ethics, feasibility, and potential for commercialization or IP.

CO5: Demonstrate teamwork, project management, and professional technical communication through reports and presentations.

CO6: Engage in self-directed learning and continuous improvement to enhance domain expertise and professional growth.

Guidelines for the Mini Project

• Projects should align with the Honors/Minor specialization domain
Mini project may be carried out in one or more form of following:
Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software

development, integration of software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc.

- **Students must form groups of 3 to 4 members.**
- **Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty.**
- **An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted.**
- **Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor.**
- **Faculty input should emphasize guiding by faculty and self-learning by group members.**
- **Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model.**
- **The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report.**
- **With the focus on self-learning, innovation, research orientation, addressing societal and industry challenges, and developing entrepreneurship qualities among students, the Mini Project should reflect appropriate depth, technical sophistication, specialization-domain relevance, and quality. Students are encouraged to adopt an innovative approach, explore emerging technologies, and demonstrate prototype development, domain-specific research outputs, or commercialization potential, rather than limiting to basic model implementation.**

In-Semester Continuous Assessment and End-Semester Examination Guidelines

- **The coordinating Head of the Department will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations in a semester.**
- **Assessment will be based on individual contributions, understanding, and responses to questions asked.**
- **Continuous Assessment marks distribution (50 marks):**
  - **20 marks for the Topic Approval Presentation in front of the progress monitoring committee**
  - **20 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee**
  - **10 marks for regularity & active participation**

The review/progress monitoring committee will assess projects based on the following criteria.

- **Theoretical solution completion, including component/system selection/design of software solution and cost analysis.**
- **Two reviews will occur:**
  - **The first review will focus on finalizing the problem statement (topic approval).**
  - **Second review will assess the progress of building a working prototype. (Mid Semester Presentation)**

In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:

1. **Quality of survey and need identification aligned with specialization or societal/industry relevance.**
2. **Clarity and innovativeness in problem definition and solution Clarity, originality, and innovativeness in problem definition, solution approach, and use of advanced tools/techniques.**
3. **Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.**
4. **Completeness and full functioning of the working model.**
5. **Effective use of skill sets and engineering norms.**
6. **Verification & validation of the solutions/test cases.**

7. Individual contributions to the group.
8. Clarity in written and oral communication.
9. Participation in research paper presentation, domain-specific competitions, hackathons, demonstrations, start-up pitching, or innovation challenges.

End-Semester Examination (50 marks):

1. **Presentation and demonstration to internal and external examiners: 20 marks.**
2. **Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.**

Curriculum Structure for Honours/Minor Degree Program in 'Additive Manufacturing'

Course Type	Sem	Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
				L	P	T	L	P	T	Total
HMC	V	HMCAM501	CAD Modeling	3	--	--	3	--	--	3
HMC	VI	HMCAM602	Bio Modeling	3	--	--	3	--	--	3
HMC	VII	HMCAM703	3D Printing Technologies I	4	--	--	4	--	--	4
HML	VII	HMLAM701	Digital Manufacturing Laboratory	--	4	--	--	2	--	2
HMC	VIII	HMCAM804	3D Printing Technologies II	4	--	--	4	--	--	4
HMP	VIII	HMPAM801	Mini Project	--	6	--	--	2	--	2
Total				**14**	**10**	**--**	**14**	**04**	**--**	**18**

Examination Scheme for Honours/Minor Degree Program in 'Additive Manufacturing'

Course Type	Sem	Course Code	Course Name	In-Semester Assessment		End Sem Exam (ESE)	Exam duration for Theory (in Hrs)		
				Continuous Assessment	Mid Sem Exam		Mid Sem	End Sem	Total
HMC	V	HMCAM501	CAD Modeling	20	30	50	1.5	2	100
HMC	VI	HMCAM602	Bio Modeling	20	30	50	1.5	2	100
HMC	VII	HMCAM703	3D Printing Technologies I	20	30	50	1.5	2	100
HML	VII	HMLAM701	Digital Manufacturing Laboratory	50	--	--	--	--	50
HMC	VIII	HMCAM804	3D Printing Technologies II	20	30	50	1.5	2	100
HMP	VIII	HMPAM801	Mini Project	50	--	--	--	--	50
Total				**180**	**120**	**250**	**--**	**--**	**550**

Course Type	Course Code	Course Name	Credits
HMC	HMCAM703	3D PRINTING TECHNOLOGIES – I	04

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. HMCAM501 - CAD Modeling
2. HMCAM602 - Bio Modeling

Program Outcomes addressed:

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO3: Design/Development of Solutions
4. PO5: Modern Tool Usage
5. PO6: The Engineer and Society
6. PO 8: Individual and team work
7. PO9: Communication
8. PO11: Lifelong Learning

Course Objectives:

1. Acquaint students with the extrusion-based 3D printing principles and material deposition mechanisms.
2. Familiarize students with resin-based 3D printing technologies, their materials and industrial applications.
3. Impart knowledge on operation, setup and software of FDM machines.
4. Enable students to Illustrate the applications of 3D printing across various industrial sectors.
5. Acknowledge to develop CAD file preparation, slicing parameters and printing workflow..
6. Integrate students to 3D printer operation, slicing settings, and integration of VR/AR visualization.

Module	Details	Hrs.
	Course Introduction This course introduces the fundamental principles, processes and workflows in additive manufacturing, focusing on Material Extrusion (FDM/FFF) and Resin-based 3D printing technologies. Students will learn hardware components, materials, slicing operations and post-processing methods used in modern 3D printing. The course also covers industrial applications, process parameters and	**01**

	workflow optimization through CAD integration and slicing software, providing a foundation for hands-on printing experience.	
01.	**Material Extrusion Process** ***Learning Objective:*** *Understand the basic principles and mechanism of extrusion-based additive manufacturing processes.* **Contents:** Introduction to Fused Deposition Modelling (FDM), Basic Principles of extrusion-based system - Material Loading, Liquification, Extrusion, Solidification, Positional Control, Bonding and Support Generation. ***Self-Learning Topics:*** *Adaptive extrusion and support optimization.* ***Learning Outcomes:*** *A learner will be able to* *LO 1.1: Apply fundamental engineering concepts to analyze material loading, liquification, extrusion, and solidification processes involved in Fused Deposition Modelling (FDM). (PI 1.3.1)* *LO 1.2 Apply mechanical engineering principles to evaluate, support generation in extrusion-based FDM systems. (PI 1.4.1)* *LO 1.3: Identify key system variables and process parameters such as feed rate, temperature, nozzle motion, and layer characteristics that influence FDM performance. (PI 2.1.2)* *LO 1.4: Identify the mathematical and engineering knowledge required to select suitable parameters such as extrusion temperature, flow rate, and deposition speed for FDM processes. (PI 2.1.3)*	**6-7**
02.	**Resin 3D Printing** ***Learning Objective:*** *Learn photo polymerization-based 3D printing processes, their materials and advantages.* **Contents:** Overview of Resin 3D Printing, Working of Resin 3D Printing, Types of Resin 3D Printing Technologies, Resin 3D Printing vs. Filament 3D Printing, Materials in Resin 3D Printing, Applications, Advantages ***Self-Learning Topics:*** *Post-curing and resin handling safety.* ***Learning Outcomes:*** *A learner will be able to* *LO 2.1:* Apply *fundamental engineering concepts to assess the working principles of resin-based 3D printing technologies. (PI 1.3.1)* *LO 2.2: -* Apply *mechanical engineering concepts to* analyze *the behaviour of resin materials to* address *print-quality. (PI 1.4.1)* *LO 2.3:* Identify *key system variables like, light intensity, exposure time, resin viscosity, layer thickness and operational parameters, etc., in resin 3D printing necessary to* formulate *solutions for print accuracy and efficiency. (PI 2.1.2)* *LO 2.4:* Compare and evaluate *SLA, DLP, and LCD resin printing processes to* select *the most suitable technology for specific applications based on performance, speed, and resolution. (PI 2.2.4)*	**7-8**

	LO 2.5: Identify *potential risks and life-cycle impacts of resin 3D printing—including chemical handling hazards, environmental exposure, and waste generation, etc., to support safe operational decisions. (PI 6.3.1)* *LO 2.6:* Propose *strategies for minimizing resin waste, emissions, and environmental impact, throughout the resin printing workflow. (PI 6.4.2)*	
03.	**Fused Deposition Modelling Machine and its Software** ***Learning Objective:*** *Explore hardware, software and operational parameters of FDM machines.*	**7-9**
	Contents: FDM Machine – Technical Specification, Main Parts, Supplies and Accessories of FFF Machine, Features, Functionalities and Requirements of CAD Software, pre-processing, printing and post processing for FDM Machine printed parts.	
	Self-Learning Topics: *Preventive maintenance and calibration of FDM machines.*	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Apply fundamental engineering concepts to select suitable FDM machine specifications for given manufacturing requirements. (PI 1.3.1)* *LO 3.2: Apply mechanical engineering principles to identify the major software parameters to be considered during preprocessing. (PI 1.4.1)* *LO 3.3: Identify key system variables and machine parameters (temperature, speed, layer height, material type, etc.) that influence print quality in an FDM workflow. (PI 2.1.2)* *LO 3.4:* *Hands-on 3D printing task to demonstrate additive manufacturing process sequence. (PI 2.3.1, 3.1.6, 3.2.2, 5.1.1, 5.1.2, 5.2.2, 6.3.1, 6.4.2, 8.1.2, 8.3.1, 9.1.2, 9.3.1, 11.3.1)* *A Task-Based Group Activity (max 4 students per group), to be completed before MSE* *Details of the task* *A. Design and Model Creation: Create a simple component (CAD) suitable for both FDM and resin printing.* *B. Pre-Processing: Prepare models for printing in respective software (slicing, orientation, support generation).* *C. Printing: Perform FDM and resin prints with optimized parameters and document settings.* *D. Post-Processing: Remove supports, check accuracy and surface finish.* *E. Documentation: Compare results between FDM and resin prints on strength, accuracy and finish. Submit a technical report.*	
04.	**Applications of Fused Deposition Modelling** ***Learning Objectives:*** *Develop skills in the industrial and societal applications of additive manufacturing.*	**6-7**
	Contents: 3D Printing in the Consumer Goods Industry, Medical Industry, Automotive Industry, Aerospace, Dental Applications, Prosthetics, Architecture, Archaeology, Art Restoration, Forensics, Film Industry and Education	
	Self-Learning Topics: *Sustainability and recycling of 3D printing materials.*	
	Learning Outcomes:	

	A learner will be able to *LO 4.1: Apply fundamental engineering concepts to identify FDM applications across industries in consumer goods, medical, automotive, aerospace and other sectors. (1.3.1)* *LO 4.2: Apply mechanical engineering fundamentals to match FDM capabilities (strength, material behaviour, geometry etc.) with real-world industrial needs. (1.4.1)* *LO 4.3: Identify the engineering systems, key variables and application-specific parameters involved in using FDM technology across industries such as automotive, medical, aerospace, and consumer goods. (PI 2.1.2)* *LO 4.4: Compare application requirements among industries and select appropriate process parameters. (PI 2.2.4)* *LO 4.5: Identify potential life-cycle risks and performance impacts associated with implementing FDM-based applications in domains such as prosthetics, forensics, architecture, and education. (PI 6.3.1)* *LO 4.6: Apply preventive engineering principles and sustainable development considerations while evaluating the use of FDM technology in industrial and non-industrial applications. (PI 6.4.2)*	
05.	**CAD File Preparation, Process Parameters and Workflow** ***Learning Objective/s:*** *Examine and gain understanding of digital preparation, slicing and process parameters affecting print quality.*	**7-8**
	Contents:	
	Steps to 3D Print a Model – Modelling, Slicing, Printing and Post-processing, Process Parameters influencing the FFF Process – Machine Parameters and Material Parameters, FFF 3D Printing Workflow – Create, Convert, Manipulate, Prepare, Build and Process, Quality Issues in FFF	
	Self-Learning Topics: *Optimization of slicing parameters for time vs. quality trade-offs.*	
	Learning Outcomes : *A learner will be able to* *LO 5.1: Apply fundamental engineering concepts to select suitable modelling, slicing, and printing steps for a given FFF task. (PI 1.3.1)* *LO 5.2: Apply mechanical engineering concepts to determine appropriate machine and material parameters influencing extrusion, layer adhesion, and dimensional accuracy. (PI 1.4.1)* *LO 5.3: Identify key machine variables (e.g., nozzle temperature, print speed, layer height) and material parameters influencing part quality and printing success. (PI 2.1.2)* *LO 5.4: Compare and select suitable modelling, slicing, and printing strategies to address quality issues of FFF workflow. (PI 2.2.4)*	
06.	**Printing in Fused Deposition Modelling (FDM)** ***Learning Objective/s:*** *Perform actual 3D printing operations and explore visualization via VR and AR.*	**8-9**
	Contents: Overview and Interface of Ideamaker Software, Printing of 3D model - Import 3D Models, Slice the model, Estimated Print Result, Save the sliced G-Code files, Slicing Setting – Layer, Extruder, Infill, Support, Temperature, Speed, cooling etc., Filament Setting, Printer Setting	

	Virtual reality: Definition, features of VR, Technologies used in VR, Introduction to Augmented reality	
	Self-Learning Topics: *Digital Twin Technology, AI in Personalized Medicine, Future of Bio-Modelling*	
	Learning Outcomes:	
	A learner will be able to *LO 6.1: Identify key system parameters such as layer height, infill, support type, print speed, etc., to solve slicing-related printing problems. (PI 2.3.1)* *LO 6.2: Assess machine capabilities for 3D printing the part/product, of required quality. (PI 2.4.4)* *LO 6.3:* *Hands-on 3D printing task to 3D print a real life product and use VR/AR tools for validation and presentation of the same. (PI 1.3.1, 1.4.1, 2.1.1, 2.2.4, 3.1.6, 3.2.2, 5.1.1, 5.1.2, 5.2.2, 6.3.1, 6.4.2, 8.1.2, 8.3.1, 9.1.2, 9.3.1, 11.3.1).* *A Task-Based Group Activity (max 4 students per group), to be completed after MSE* *Details of the task* *A. Problem Definition: Select an industrial application component (e.g., medical prosthetic, automotive bracket).* *B. Pre-Processing: Design/modify CAD model, apply process parameters and simulate build using slicer.* *C. Printing & Post-Processing: Execute print operation, remove supports, inspect for defects and measure accuracy.* *D. Visualization: Use VR/AR tools to present assembly and fit validation of printed parts.* *E. Documentation:: Prepare a technical report covering problem, settings, results and future improvements.*	
	Course Conclusion Upon completion, learners will be capable of setting up, operating, and troubleshooting 3D printers, understanding material behavior, process parameters, and workflows in both filament and resin-based systems. They will also gain insight into visualization tools like VR and AR, supporting modern manufacturing design validation and communication.	**01**
	Total	**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis
3.1.6	Determine design objectives, functional requirements and arrive at specifications

3.2.2 Build models/prototypes to develop a diverse set of design solutions

5.1.1 Identify modern engineering tools such as computer-aided drafting, modeling and analysis; techniques and resources for engineering activities

5.1.2 Create/adapt/modify/extend tools and techniques to solve engineering problems

5.2.2 Demonstrate proficiency in using discipline-specific tools

6.3.1 Identify risks/impacts in the life-cycle of an engineering product or activity

6.4.2 Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline

8.1.2 Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.

8.3.1 Present results as a team, with smooth integration of contributions from all individual efforts

9.1.2 Produce clear, well-constructed, and well-supported written engineering documents

9.3.1 Create engineering-standard figures, reports and drawings to complement writing and presentations

11.3.1 Source and comprehend technical literature and other credible sources of information.

Course Outcomes: A learner will be able to

1. Identify important process variables, to select suitable FDM parameters. (*LO 1.1, LO 1.2, LO 1.3, LO 1.4*)
2. Compare and evaluate resin-based 3D printing technologies, material characteristics and their suitability for industrial applications. (*LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 2.6)*
3. Demonstrate the setup, calibration and operational workflow of Fused Deposition Modelling (FDM) machines using appropriate software tools. (*LO 3.1, LO 3.2, LO 3.3, LO 3.4)*
4. Identify the utilization of additive manufacturing technologies across multiple industrial sectors and assess their impact on product development. (*LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 4.6)*
5. Develop 3D printed products from CAD models, by applying suitable slicing parameters, designing efficient printing workflows and use VR/AR for visualization. (*LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 6.1, LO 6.2, LO 6.3)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCAM703.1	3	3	--	--	--	--	--	--	--	--	--
HMCAM703.2	3	3	--	--	--	3	--	--	--	--	--
HMCAM703.3	3	3	3	--	3	3	--	3	3	--	2
HMCAM703.4	3	3	--	--	--	3	--	--	--	--	--
HMCAM703.5	3	3	3	--	3	3	--	3	3	--	2
Average	**3**	**3**	**3**	**--**	**3**	**3**	**--**	**--**	**3**	**--**	**2**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Ian Gibson et al., Additive Manufacturing Technologies, Springer, 3rd Ed., 2021.
2. Andreas Gebhardt, Understanding Additive Manufacturing, Hanser, 2011.
3. C.K. Chua et al., Rapid Prototyping: Principles and Applications, World Scientific, 3rd Ed., 2010.
4. Chee Kai Chua & K.F. Leong, 3D Printing and Additive Manufacturing: Principles and Applications, World Scientific, 5th Ed., 2021.
5. Ian Gibson et al., Additive Manufacturing Technologies, Springer, 3rd Ed., 2021.

Reference Books :

1. Kalpakjian S. & Schmid S., Manufacturing Engineering and Technology, Pearson, 8th Ed., 2020.
2. Amit Bandyopadhyay & Susmita Bose, Additive Manufacturing, CRC Press, 2015.
3. S.K. Singh, 3D Printing Technology: Innovations and Applications, Elsevier, 2020.
4. H.K. Versteeg & W. Malalasekera, An Introduction to Computational Fluid Dynamics, Pearson, 2007.

Other Resources :

1. NPTEL Course: Additive Manufacturing (IIT Guwahati)
Web link: https://nptel.ac.in/courses/112/103/112103174

<u>IN-SEMESTER ASSESSMENT (50 MARKS)</u>

1. Continuous Assessment - Theory-(20 Marks)

<u>Suggested breakup of distribution</u>

A task based group activity, before MSE	:	05 Marks
A task based group activity, after MSE	:	05 Marks
Article reading and summarization	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

<u>END SEMESTER EXAMINATION (50 MARKS)</u>

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
HML	HMLAM701	DIGITAL MANUFACTURING LABORATORY	02

Examination Scheme		
Continuous Assessment	**End Semester Exam (ESE)**	**Total**
50	--	50

Pre-requisite:

1. HMCAM501 - CAD Modeling
2. HMCAM602 - Bio Modeling

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/Development of Solutions
4. PO5: Modern tool usage
5. PO9: Communication

Course Objectives:

1. Introduce students to the fundamentals of geometric modelling and feature creation in CAD and the use of various CAD tools to create parts..
2. Teach students how to construct assemblies, perform interference checks and prepare engineering drawings.
3. Familiarize students with 3D scanning, mesh processing and reverse engineering.
4. Introduce students to generate toolpaths and create freeform geometries for digital manufacturing.
5. Teach students the complete process to perform segmentation, image-based modelling and additive manufacturing operations.

Module	Details	Hrs.
	Course Introduction Hands-on skills in 3D modelling, assembly creation, drafting and 3D printing using industry-standard digital manufacturing tools. Emphasis is placed on feature-based modelling, parametric design, toolpath generation, scanning and data exchange workflows required for real-world engineering applications.	**01**
01.	**Geometric & Feature-Based Modeling** ***Learning Objective:*** *Understand how to apply 2D and 3D CAD operations for geometric and feature-based modelling of engineering components.*	**11**

	Contents: **Task 1A** Perform geometric modelling of an engineering component by using sketching commands such as line, arc, circle, and apply modification tools including trim, move, rotate, along with viewing tools like pan, zoom and rotate to create the required sketch profile. ***Learning Outcomes:*** *A learner will be able to* *LO 1.1: Apply fundamental engineering concepts to create geometric models using CAD sketching and modification tools. (PI 1.3.1, 1.4.1, 2.1.2, 2.1.3, 3.1.6, 5.1.1, 5.2.2, 9.1.1, 9.1.2, 9.3.1)* **Task 1B** Demonstrate solid and surface modelling skills by using commands such as extrude, revolve, sweep, blend and loft and perform feature manipulation operations including copy, edit, pattern, suppress and history management to generate the final model. ***Learning Outcomes:*** *A learner will be able to* *LO 1.2: Identify engineering systems, variables and parameters to construct feature-based solid and surface models. (PI 1.3.1, 2.1.2, 2.1.3, 3.1.3, 3.1.6, 5.1.1, 5.1.2, 5.2.2, 9.1.1, 9.3.1)*	
	Self-Learning Topics: *Reference geometry, constraints, parametric modelling, solid vs surface modelling.*	
02.	**Assembly, Drafting & Solid Modeling** ***Learning Objective:*** *Apply assembly constraints to accurately position, perform interference checks and prepare engineering drawings.*	**12**
	Contents: **Task 2A** Create a CAD assembly using appropriate constraints, generate exploded views, perform interference checks and prepare detailed engineering drawings including layouts, standard views, sectional views and annotations as per drafting standards. ***Learning Outcomes:*** *A learner will be able to* *LO 2.1: Determine design objectives and functional requirements to construct assemblies and engineering drawings. (PI 1.3.1, 1.4.1, 2.1.2, 2.1.3, 3.1.3, 3.1.6, 5.1.1, 5.2.2, 9.1.1, 9.3.1)* **Task 2B** Develop a complete solid model of an engineering component using any 3D modelling software, applying suitable modelling strategies and maintaining design intent. ***Learning Outcomes:*** *A learner will be able to* *LO 2.2: Develop a parametric assembly of engineering components and apply basic assembly verification techniques to create accurate solid models and drawings. (PI 1.3.1, 2.1.2, 2.1.3, 3.1.6, 5.1.1, 5.2.2, 9.1.1, 9.1.2, 9.3.1)*	

	Self-Learning Topics: *GD&T, fits and tolerances, assembly standards.*	
03.	**Scanning & Reverse Engineering** ***Learning Objective:*** *Understand how to perform 3D scanning, mesh processing and model reconstruction.*	**12**
	Contents: **Task 3A** Carry out non-contact scanning of a physical component using 3D scanning equipment and generate a CAD-compatible model by processing the captured point cloud or mesh data. ***Learning Outcomes:*** *A learner will be able to* *LO 3.1: Identify engineering systems, variables and parameters to generate accurate CAD models from scanned data. (PI 1.3.1, 2.1.2, 2.1.3, 3.1.3, 5.1.1, 5.2.2, 9.1.1, 9.1.2, 9.3.1)* **Task 3B** Perform reverse engineering of a legacy component by selecting an appropriate part, conducting 3D scanning, verifying and refining the CAD model and fabricating the reconstructed part using 3D printing. ***Learning Outcomes:*** *A learner will be able to* *LO 3.2: Apply engineering concepts to refine, verify and reconstruct CAD models during reverse engineering workflows. (PI 1.3.1, 1.4.1, 2.1.3, 3.1.6, 5.1.1, 5.2.2, 9.1.1, 9.1.2, 9.3.1)*	
	Self-Learning Topics: *STL repair, mesh refinement, point cloud filtering.*	
04.	**Toolpath Generation & Freeform Modeling** ***Learning Objectives:*** *Learn to generate toolpaths and create freeform geometries for digital manufacturing.*	**12**
	Contents: **Task 4A** Model a mechanical component using 3D modelling tools and generate the corresponding G-code by applying appropriate toolpath strategies and process parameters required for digital manufacturing. ***Learning Outcomes:*** *A learner will be able to* *LO 4.1: Apply engineering and mathematical knowledge to generate toolpaths and G-Code for manufacturing workflows. (PI 1.3.1, 2.1.2, 2.1.3, 3.1.3, 5.1.1, 5.2.2, 9.1.1, 9.1.2, 9.3.1)* **Task 4B** Design a free-form object using Autodesk Fusion 360 and develop the toolpath and G-code output to prepare the model for manufacturing. ***Learning Outcomes:*** *A learner will be able to* *LO 4.2: Create and modify toolpaths for freeform geometries using CAD/CAM tools. (PI 1.3.1, 2.1.3, 3.1.6, 5.1.1, 5.1.2, 5.2.2, 9.1.1, 9.3.1)*	

	Self-Learning Topics: *Slicing strategies, feed rate, toolpath optimisation.*	
05.	**Bio-Modelling & Additive Manufacturing Applications** ***Learning Objective/s:*** *Perform segmentation, image-based modelling and additive manufacturing workflows.*	**12**
	Contents: **Task 5A** Perform segmentation of medical image data using Slicer's Segment Editor module to generate a 3D printable anatomical model. **Task 5B** Create a 3D model from 2D medical images using suitable image-processing tools and fabricate the model using 3D Slicer-based workflows. ***Learning Outcomes:*** *A learner will be able to* *LO 5.1: Identify engineering systems and parameters for generating printable bio-models from medical imaging data.* (PI 1.3.1, 1.4.1, 2.1.2, 2.1.3, 3.1.3, 5.1.1, 5.2.2, 9.1.1, 9.3.1) **Task 5C** Develop a physical 3D mechanical structure using any suitable metal-based additive manufacturing process. **Task 5D** Develop a physical 3D mechanical structure using any suitable polymer-based additive manufacturing process. ***Learning Outcomes:*** *A learner will be able to* *LO 5.2: Demonstrate proficiency in metal and polymer additive manufacturing to fabricate engineered components. (PI 1.3.1, 2.1.3, 3.1.6, 5.1.1, 5.1.2, 5.2.2, 9.1.1, 9.3.1)*	
	Self-Learning Topics: *DICOM processing, segmentation filters, AM process parameters.*	
	Total	**60**

P.I. No.	**P.I. Statement**
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem.
3.1.3	Synthesize engineering requirements from a review of the state-of-the-art
3.1.6	Determine design objectives, functional requirements and arrive at specifications
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling and analysis; techniques and resources for engineering activities.
5.1.2	Create/adapt/modify/extend tools and techniques to solve engineering problems
5.2.2	Demonstrate proficiency in using discipline-specific tools.
9.1.1	Read, understand and interpret technical and non-technical information
9.1.2	Produce clear, well-constructed, and well-supported written engineering documents

9.1.3 Create flow in a document or presentation - a logical progression of ideas so that the main point is clear

Course Outcomes: Learner will be able to

1. Apply geometric and feature-based modelling techniques using CAD tools. *(LO 1.1, LO 1.2)*
2. Build and validate CAD assemblies with parametric constraints, detect interference and generate engineering drawings. *(LO 2.1, LO 2.2)*
3. Perform 3D scanning and reverse engineering workflows. *(LO 3.1, LO 3.2)*
4. Generate toolpaths and freeform modelling using CAD/CAM tools. *(LO 4.1, LO 4.2)*
5. Apply segmentation, bio-modelling and AM workflows. *(LO 5.1)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMLAM701.1	3	3	3	--	3	--	--	--	3	--	--
HMLAM701.2	3	3	3	--	3	--	--	--	3	--	--
HMLAM701.3	3	3	3	--	3	--	--	--	3	--	--
HMLAM701.4	3	3	3	--	3	--	--	--	3	--	--
HMLAM701.5	3	3	3	--	3	--	--	--	3	--	--
Average	**3**	**3**	**3**	**--**	**3**	**--**	**--**	**--**	**3**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. SolidWorks for Designers, Sham Tickoo, CADCIM Technologies.
2. CATIA V5 Workbook, Sandeep Sharma, CADCIM Technologies.
3. CAD/CAM: Theory and Practice, Ibrahim Zeid, McGraw-Hill.
4. CAD/CAM Principles & Practice, McMahon & Browne, Pearson.

Reference Books :

1. Additive Manufacturing Technologies, Gibson, Rosen & Stucker, Springer.
2. Understanding Additive Manufacturing, Gebhardt, Hanser.
3. Reverse Engineering, Raja & Fernandus, CRC Press.
4. Digital Manufacturing & Design, Zhao & Zhang, Elsevier.

5. Medical Imaging & 3D Reconstruction, Marc Levoy.

Other Resources :

1. NPTEL Course: Computer Aided Design and Manufacturing – Prof. Janakarajan Ramkumar (IIT Kanpur).
   Web link: https://onlinecourses.nptel.ac.in/noc25_me11/preview
2. NPTEL Course: Product Design and Development – Prof. Inderdeep Singh (IIT Roorkee)
   Web link: https://onlinecourses.nptel.ac.in/noc21_me83/preview
3. NPTEL Course: Metal Additive Manufacturing – Prof. J. Ramkumar, Prof. A. S. Oberoi (IIT Kanpur)
   Web link: https://onlinecourses.nptel.ac.in/noc25_me130/preview
4. NPTEL Course: Advances in Additive Manufacturing of Materials – IIT Bombay (NPTEL)
   Web link: https://onlinecourses.nptel.ac.in/noc26_mm14/preview
5. NPTEL Course: Medical Image Analysis – Prof. Ganapathy Krishnamurthi (IIT Madras)
   Web link: https://nptel.ac.in/courses/108/105/108105091/

IN-SEMESTER ASSESSMENT (50 MARKS)

Continuous Assessment (50 Marks)

Suggested breakup of distribution

Practical performance based on all the experiments mentioned in the syllabus with proper understanding	:	25 marks
Task-based Group Project (maximum 4 students) involving scanning, reverse engineering, toolpath generation or additive manufacturing workflows (maximum 4 students)	:	20 marks
Regularity and active participation	:	05 marks

Course Type	Course Code	Course Name	Credits
HMC	HMCAM804	3D PRINTING TECHNOLOGIES – II	04

<table>
<tr><th colspan="6">Examination Scheme</th></tr>
<tr><th colspan="3">Distribution of Marks</th><th colspan="2" rowspan="2">Exam Duration (Hrs.)</th><th rowspan="3">Total Marks</th></tr>
<tr><th colspan="2">In-semester Assessment</th><th rowspan="2">End Semester Examination (ESE)</th></tr>
<tr><th>Continuous Assessment</th><th>Mid-Semester Exam (MSE)</th><th>MSE</th><th>ESE</th></tr>
<tr><td>20</td><td>30</td><td>50</td><td>1.5</td><td>2</td><td>100</td></tr>
</table>

Pre-requisite:

1. HMCAM501 - CAD Modeling
2. HMCAM602 - Bio Modeling
3. HMCAM703 - 3D Printing Technologies - I

Program Outcomes addressed:

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO3: Design/Development of Solutions
4. PO5: Modern Tool Usage
5. PO6: The Engineer and the World
6. PO8: Individual and Collaborative Team work
7. PO9: Communication
8. PO11: Lifelong Learning

Course Objectives:

1. Acquaint learners with liquid-based, solid-based and powder-based AM systems.
2. Familiarize learners with working principles, models, specifications, and applications of SLA, SGC, LOM, FDM, SLS, 3DP and EBM.
3. Impart understanding of AM materials, their types, characteristics, and operational behaviour.
4. Enable analysis of material performance factors such as accuracy, stability, finish, and environmental resistance.
5. Acknowledge reverse engineering, digitizing methods, medical imaging and VR/AR integration.
6. Integrate learners into AM workflows including technology comparison, material selection, process analysis and digital reconstruction.

<table>
<tr><th>Module</th><th>Details</th><th>Hrs.</th></tr>
<tr><td></td><td>Course Introduction
This course provides a comprehensive study of additive manufacturing systems beyond extrusion processes, covering liquid-based, solid-based, and powder-based technologies. Learners explore materials, machine specifications, processing workflows, and application-driven selection of AM systems. The course further introduces reverse engineering, digitizing methods, medical imaging fundamentals, and the integration of VR/AR for visualization and validation in AM product development.</td><td>01</td></tr>
<tr><td>01.</td><td>Additive Manufacturing
Learning Objective:
Understand the foundational principles, classifications, applications, and industrial relevance of additive manufacturing.
Contents:
Introduction to AM, Classification of AM processes, Advantages & disadvantages, AM applications in design, concept modelling, form & fit checking, functional testing, CAD data verification, rapid tooling, and bio-fabrication.
Self-Learning Topics:
Emerging AM classifications and hybrid manufacturing.
Learning Outcomes:
A learner will be able to
LO 1.1: Apply fundamental concepts and classifications of AM processes. (PI 1.3.1)
LO 1.2: Identify engineering parameters influencing AM advantages and limitations. (PI 2.1.2)
LO 1.3: Compare AM applications in modelling, fit-checking, tooling and bio fabrication. (PI 2.2.4)
LO 1.4: Apply mechanical engineering concepts to evaluate additive manufacturing process behavior. (PI 1.4.1)</td><td>8-10</td></tr>
<tr><td>02.</td><td>Liquid based systems
Learning Objective:
Learn SLA and SGC processes, their materials, mechanisms and industrial usage.
Contents:
Stereo lithography apparatus (SLA): Models and specifications, process, working principle, photopolymers, photo polymerization, layering technology, laser and laser scanning, applications, advantages and disadvantages, case studies.
Solid ground curing (SGC): Models and specifications, process, working, principle, applications, advantages and disadvantages, case studies.
Self-Learning Topics:
Advanced photopolymerization strategies.
Learning Outcomes:
A learner will be able to
LO 2.1: Apply engineering concepts to assess SLA and SGC working principles. (PI 1.3.1)</td><td>9-11</td></tr>
</table>

	LO 2.2: Apply mechanical/material concepts to analyse photopolymer curing behaviour. (PI 1.4.1) *LO 2.3: Identify system variables such as exposure time, resin viscosity and scan parameters affecting print results. (PI 2.1.2)* *LO 2.4: Compare SLA and SGC for suitable application selection. (PI 2.2.4)* *LO 2.5: Identify potential life-cycle risks and environmental impacts associated with liquid-based AM processes, including resin handling, waste generation and post-curing effects. (PI 6.3.1)* *LO 2.6: Propose preventive engineering practices to ensure safe handling, storage, and disposal of photopolymer materials in SLA and SGC workflows, minimizing environmental impact throughout the liquid-based AM process. (PI 6.4.2)*	
03.	**Solid-Based Systems** ***Learning Objective:*** *Explore LOM and FDM processes, their operational mechanisms and application domains.*	**9-11**
	Contents: Laminated object manufacturing (LOM): Models and specifications, Process, Working principle, Applications, Advantages and disadvantages, Case studies. Fused Deposition Modeling (FDM): Models and specifications, Process, Working principle, Applications, Advantages and disadvantages, Case studies.	
	Self-Learning Topics: *Support less lamination strategies.*	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Apply engineering concepts to select LOM/FDM processes for specified requirements. (PI 1.3.1)* *LO 3.2: Apply material behavior principles to evaluate bonding and sheet lamination. (PI 1.4.1)* *LO 3.3: Identify key engineering variables influencing LOM and FDM performance. (PI 2.1.2)* *LO 3.4:* *Hands-on additive manufacturing task to demonstrate comparative evaluation of SLA, SGC, LOM and FDM processes. (PI 2.2.4, 2.3.1, 3.1.6, 3.2.2, 5.1.1, 5.1.2, 5.2.2, 6.3.1, 6.4.2, 8.1.2, 8.3.1, 9.1.2, 9.3.1, 11.3.1)* *A Task-Based Group Activity (max 4 students per group), to be completed before MSE* *Details of the task* *F. Design and Model Creation: Create a CAD model suitable for fabrication using at least two processes among SLA, SGC, LOM and FDM.* *G. Pre-Processing: Prepare the models in appropriate AM software (orientation, slicing, scan/exposure settings, lamination parameters and support generation where required).* *H. Printing / Process Execution: Perform printing or validated simulation for each selected AM process and record all relevant parameters.* *I. Post-Processing: Evaluate dimensional accuracy, surface finish, material behavior, bonding/lamination performance and overall part quality. Remove supports, check accuracy and surface finish.* *J. Documentation: Prepare a technical report comparing outcomes across selected processes, including accuracy, finish, process behavior, material response and application suitability.*	

<table>
<tr><td>04.</td><td>Powder Based Systems

Learning Objectives:
Understand the principles, material behavior, and industrial relevance of SLS, 3DP and EBM processes.

Contents:
Selective laser sintering (SLS): Models and specifications, process, working principle, applications, advantages and disadvantages, case studies.
Three-dimensional printing (3DP): Models and specification, process, working principle, applications, advantages and disadvantages, case studies.
Electron Beam Melting (EBM): Models and specification, process, working principle, applications, advantages and disadvantages, case studies.

Self-Learning Topics:
Powder flow regulation and thermal management.

Learning Outcomes:
A learner will be able to
LO 4.1: Apply fundamental engineering concepts to describe SLS, 3DP and EBM working principles. (PI 1.3.1)
LO 4.2: Apply mechanical/material concepts to evaluate fusion and bonding in powder-based systems. (PI 1.4.1)
LO 4.3: Identify key variables such as laser power, particle size and bed temperature influencing build quality. (PI 2.1.2)
LO 4.4: Compare powder-based systems to select appropriate processes for applications. (PI 2.2.4)
LO 4.5: Identify potential life-cycle risks and environmental impacts associated with powder-based AM processes—including powder handling exposure, thermal energy use, and waste generation—to support safe and sustainable operational decisions. (PI 6.3.1)
LO 4.6: Apply preventive engineering strategies and sustainable development considerations to ensure safe handling, recycling and disposal of metallic, ceramic and polymer powders in SLS, 3DP and EBM workflows, minimizing environmental impact throughout the powder-based AM process. (PI 6.4.2)</td><td>9-11</td></tr>
<tr><td>05.</td><td>Materials for Additive Manufacturing
Learning Objective/s:
Examine and gain understanding of AM material types and their operational properties.

Contents:
Types of material: polymers, metals, ceramics and composites, liquid-based materials, photo polymer development, solid based materials, powder-based materials.
Material properties: Color, dimensional accuracy, stability, surface finish, machinability, environmental resistance, operational properties.

Self-Learning Topics:
Material testing standards in AM.

Learning Outcomes :
A learner will be able to
LO 5.1: Apply engineering fundamentals to identify suitable AM materials for specific processes. (PI 1.3.1)</td><td>8-10</td></tr>
</table>

	LO 5.2: Apply mechanical engineering concepts to assess dimensional accuracy and surface outcomes. (PI 1.4.1) *LO 5.3: Identify material-dependent variables influencing AM process selection. (PI 2.1.2)* *LO 5.4: Compare materials based on process compatibility and operational performance. (PI 2.2.4)*	
06.	**Reverse Engineering and Virtual reality** ***Learning Objective/s:*** *Understand digitizing methods, medical imaging basics and visualization through VR/AR.*	**9-11**
	Contents: Introduction to Digitizing Methods, Contact type and Non-contact type, Brief introduction to the types of Medical imaging. Virtual reality: Definition, features of VR, Features and Technologies used in VR, Introduction to Augmented reality	
	Self-Learning Topics: *Geometry reconstruction and STL repair workflows.*	
	Learning Outcomes:	
	A learner will be able to *LO 6.1: Identify engineering parameters relevant to digitizing and reconstruction. (PI 2.1.2)* *LO 6.2: Extract conclusions related to imaging suitability and reverse engineering workflows. (PI 2.4.4)* *LO 6.3:* *Hands-on reverse engineering and visualization task to demonstrate digitizing, reconstruction and powder-based AM preparation using VR/AR tools and presentation of the same. (PI 1.3.1, 1.4.1, 2.1.1, 2.2.4, 3.1.6, 3.2.2, 5.1.1, 5.1.2, 5.2.2, 6.3.1, 6.4.2, 8.1.2, 8.3.1, 9.1.2, 9.3.1, 11.3.1)* *A Task-Based Group Activity (max 4 students per group), to be completed after MSE* *Details of the task* *F. Problem Definition: Select a suitable component requiring geometry capture and reconstruction for powder-based AM (SLS / 3DP / EBM).* *G. Digitizing / Scan Data Processing: Acquire geometry using contact or non-contact scanning techniques and perform mesh cleaning, repair and refinement.* *H. Pre-Processing: Prepare the reconstructed model for powder-based AM by assigning layer parameters, scan strategy, beam/binder settings and material selection.* *I. Printing / Simulation: Execute a validated build simulation or printing trial, followed by evaluation of distortions, defects, dimensional deviations and surface characteristics.* *J. VR/AR Visualization: Use VR/AR tools for model inspection, assembly fit validation and presentation.* *K. Documentation: Prepare a technical report summarizing methodology, parameters, results, conclusions and future improvements.*	
	Course Conclusion Upon completion, Learners will understand liquid, solid and powder-based AM technologies, evaluate materials and process parameters and apply reverse engineering and VR/AR tools for AM-driven product development.	**01**
	Total	**60**

Performance Indicators:

P.I. No.	P.I. Statement
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.1	Articulate problem statements and identify objectives
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis
3.1.6	Determine design objectives, functional requirements and arrive at specifications
3.2.2	Build models/prototypes to develop a diverse set of design solutions
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling and analysis; techniques and resources for engineering activities
5.1.2	Create/adapt/modify/extend tools and techniques to solve engineering problems
5.2.2	Demonstrate proficiency in using discipline-specific tools
6.3.1	Identify risks/impacts in the life-cycle of an engineering product or activity
6.4.2	Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline
8.1.2	Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.
8.3.1	Present results as a team, with smooth integration of contributions from all individual efforts
9.1.2	Produce clear, well-constructed, and well-supported written engineering documents
9.3.1	Create engineering-standard figures, reports and drawings to complement writing and presentations
11.3.1	Source and comprehend technical literature and other credible sources of information.

Course Outcomes: A learner will be able to

1. Identify additive manufacturing principles, classifications, applications and related engineering considerations. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5)*
2. Compare and evaluate liquid-based AM technologies, their materials, parameters and environmental considerations. (*LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 2.6)*
3. Demonstrate the design, preparation and operational workflow of solid-based additive manufacturing processes through CAD modelling, pre-processing, printing/simulation and evaluation activities using appropriate software tools. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4)*
4. Identify, evaluate and compare powder-based AM processes, including sustainability and risk considerations. (*LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 4.6)*
5. Identify and assess AM materials and evaluate their process-specific suitability. *(LO 5.1, LO 5.2, LO 5.3, LO 5.4)*
6. Develop reconstructed digital models using appropriate digitizing methods, apply suitable pre-processing parameters for powder-based AM and use VR/AR tools for visualization and validation. (*LO 6.1, LO 6.2, LO 6.3)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCAM804.1	3	3	--	--	--	--	--	--	--	--	--
HMCAM804.2	3	3	--	--	--	3	--	--	--	--	--
HMCAM804.3	3	3	3	--	3	3	--	3	3	--	2
HMCAM804.4	3	3	--	--	--	3	--	--	--	--	--
HMCAM804.5	3	3	--	--	--	--	--	--	--	--	--
HMCAM804.6	3	3	3	--	3	3	--	3	3	--	2
Average	**3**	**3**	**3**	**--**	**3**	**3**	**--**	**--**	**3**	**--**	**2**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Ian Gibson et al., Additive Manufacturing Technologies, Springer, 3rd Ed., 2021.
2. Andreas Gebhardt, Understanding Additive Manufacturing, Hanser, 2011.
3. C.K. Chua et al., Rapid Prototyping: Principles and Applications, World Scientific, 3rd Ed., 2010.
4. Chee Kai Chua & K.F. Leong, 3D Printing and Additive Manufacturing: Principles and Applications, World Scientific, 5th Ed., 2021.

Reference Books :

1. Kalpakjian S. & Schmid S., Manufacturing Engineering and Technology, Pearson, 8th Ed., 2020.
2. Amit Bandyopadhyay & Susmita Bose, Additive Manufacturing, CRC Press, 2015.
3. S.K. Singh, 3D Printing Technology: Innovations and Applications, Elsevier, 2020.
4. H.K. Versteeg & W. Malalasekera, An Introduction to Computational Fluid Dynamics, Pearson, 2007.

Other Resources :

1. NPTEL Course: Additive Manufacturing (IIT Guwahati)
   Web link: https://nptel.ac.in/courses/112/103/112103174

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment – Theory (20 Marks)

Suggested breakup of distribution

A task based group activity, before MSE	:	05 Marks
A task based group activity, after MSE	:	05 Marks
Article reading and summarization	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
HMP	HMPAM801	Honours/Minor Mini Project	02

Program Outcomes addressed: 1. PO1 : Engineering knowledge 2. PO2 : Problem Analysis 3. PO3 : Design/Development of Solutions 4. PO4 : Conduct investigations of complex problems 5. PO5 : Modern Tool Usage 6. PO6 : The Engineer & World 7. PO7 : Ethics 8. PO8 : Individual & team work 9. PO9 : Communication 10. PO10: Project Management & Finance 11. PO11: Life-long learning
Course Objectives 1. To guide students in identifying specialization-domain problems 2.. To explore advanced solutions using emerging technologies and specialized tools. 3. To develop research aptitude, innovation mindset, entrepreneurship potential, and lifelong learning skills. 4.. To foster self-directed learning, domain-specific competency, and collaboration.
Course Outcomes At the end of the course, students will be able to: CO1: Identify and articulate a domain-relevant societal, industrial, or research problem using literature review and analysis. CO2: Apply engineering principles and specialized tools to design innovative and feasible technical solutions. CO3: Conduct investigations, simulations, or experiments to validate the proposed solution using appropriate methods. CO4: Evaluate the solution considering sustainability, ethics, feasibility, and potential for commercialization or IP. CO5: Demonstrate teamwork, project management, and professional technical communication through reports and presentations. CO6: Engage in self-directed learning and continuous improvement to enhance domain expertise and professional growth.
Guidelines for the Mini Project
• Projects should align with the Honors/Minor specialization domain Mini project may be carried out in one or more form of following: Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software development, integration of software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc. • Students must form groups of 3 to 4 members.

• Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty.
• An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted.
• Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor.
• Faculty input should emphasize guiding by faculty and self-learning by group members.
• Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model.
• The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report.
• With the focus on self-learning, innovation, research orientation, addressing societal and industry challenges, and developing entrepreneurship qualities among students, the Mini Project should reflect appropriate depth, technical sophistication, specialization-domain relevance, and quality. Students are encouraged to adopt an innovative approach, explore emerging technologies, and demonstrate prototype development, domain-specific research outputs, or commercialization potential, rather than limiting to basic model implementation.

In-Semester Continuous Assessment and End-Semester Examination Guidelines

- **The coordinating Head of the Department will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations in a semester.**
- **Assessment will be based on individual contributions, understanding, and responses to questions asked.**
- **Continuous Assessment marks distribution (50 marks):**
    - **20 marks for the Topic Approval Presentation in front of the progress monitoring committee**
    - **20 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee**
    - **10 marks for regularity & active participation**

The review/progress monitoring committee will assess projects based on the following criteria.

- **Theoretical solution completion, including component/system selection/design of software solution and cost analysis.**
- **Two reviews will occur:**
    - **The first review will focus on finalizing the problem statement (topic approval).**
    - **Second review will assess the progress of building a working prototype. (Mid Semester Presentation)**

In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:

1. **Quality of survey and need identification aligned with specialization or societal/industry relevance.**
2. **Clarity and innovativeness in problem definition and solution Clarity, originality, and innovativeness in problem definition, solution approach, and use of advanced tools/techniques.**
3. **Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.**
4. **Completeness and full functioning of the working model.**
5. **Effective use of skill sets and engineering norms.**
6. **Verification & validation of the solutions/test cases.**
7. **Individual contributions to the group.**
8. **Clarity in written and oral communication.**

9. Participation in research paper presentation, domain-specific competitions, hackathons, demonstrations, start-up pitching, or innovation challenges.

End-Semester Examination (50 marks):

1. **Presentation and demonstration to internal and external examiners: 20 marks.**
2. **Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.**

Curriculum Structure for Honours/Minor Degree Program in 'Supply Chain'

Course Type	Sem	Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
				L	P	T	L	P	T	Total
HMC	V	HMCSC501	Fundamentals of Logistics Management	3	--	--	3	--	--	3
HMC	VI	HMCSC602	Operations and Supply Chain Management	3	--	--	3	--	--	3
HMC	VII	HMCSC703	Project Management in Supply Chain	4	--	--	4	--	--	4
HML	VII	HMLSC701	Logistics Supply Chain Management Laboratory	--	4	--	--	2	--	2
HMC	VIII	HMCSC804	Quality Management in Supply Chain	4	--	--	4	--	--	4
HMP	VIII	HMPSC801	Mini Project	--	6	--	--	2	--	2
Total				**14**	**10**	**--**	**14**	**04**	**--**	**18**

Examination Scheme for Honours/Minor Degree Program in 'Supply Chain'

Course Type	Sem	Course Code	Course Name	In-Semester Assessment		End Sem Exam (ESE)	Exam duration for Theory (in Hrs)		
				Continuous Assessment	Mid Sem Exam		Mid Sem	End Sem	Total
HMC	V	HMCSC501	Fundamentals of Logistics Management	20	30	50	1.5	2	100
HMC	VI	HMCSC602	Operations and Supply Chain Management	20	30	50	1.5	2	100
HMC	VII	HMCSC703	Project Management in Supply Chain	20	30	50	1.5	2	100
HML	VII	HMLSC701	Logistics Supply Chain Management Laboratory	50	--	--	--	--	50
HMC	VIII	HMCSC804	Quality Management in Supply Chain	20	30	50	1.5	2	100
HMP	VIII	HMPSC801	Mini Project	50	--	--	--	--	50
Total				**180**	**120**	**250**	**--**	**--**	**550**

Course Type	Course Code	Course Name	Credits
HMC	HMCSC703	PROJECT MANAGEMENT IN SUPPLY CHAIN	04

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. HMCSC501 - Fundamentals of Logistics Management
2. HMCSC602 - Operations and Supply Chain Management

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/development of solutions
4. PO7: Ethics
5. PO8: Individual and team work
6. PO9: Communication
7. PO10: Project management and finance
8. PO11: Life-long learning

Course Objectives :

1. To comprehend how project management methodologies are applied specifically within the context of supply chain operations.
2. To acquaint with the techniques of scope, time, cost and communication management to achieve project goals.
3. To become familiar with various scheduling strategies for effective project management.
4. To acquaint with the supply chain processes across different regions and business units globally.

Module	Details	Hrs
	Course Introduction The course "Project Management in Supply Chain" is intended to give students with the fundamental information and skills required to effectively manage projects within a supply chain. Whether a learner is new to project management or has some experience, this course will provide him or her with the necessary tools and techniques to succeed in the dynamic and complex sector of supply chain management. The course briefly covers the foundations of project management, scope management, time management, cost management, and communication management within the framework of SCM. The course also covers various	**01**

	scheduling techniques for project management and closes with a brief overview of SCM in a global scenario.	
01.	**Introduction to Project Management** ***Learning Objective:*** *To gain the knowledge of fundamentals of project management and identify the phases of project life cycle.*	**7-9**
	Contents:	
	Definitions and key concepts, Importance of project management in supply chains, Role of a project manager in supply chain projects Project life cycle phases: Initiation, Planning, Execution, Monitoring & Control, and Closure. Organizational structures in project management, Stakeholder identification and analysis, Project governance and ethics	
	Learning Outcomes : *A learner will be able to* *LO1.1: Apply engineering concepts to address scope, time, cost, quality, and risk in supply chain projects.(P.I. 1.3.1)* *LO1.2: Apply project management concepts to develop a simple project plan including objectives, deliverables, and milestones (P.I. 1.4.1)* *LO1.3: Identify internal and external stakeholders in a supply chain project. (P.I.- 2.1.2)* *LO1.4: Identify ethical issues and dilemmas in supply chain project management. (P.I.- 2.1.3, P.I.- 7.1.1, P.I.- 7.2.2)*	
02.	**Scope Management and Time Management in Supply Chains** ***Learning Objectives:*** *To familiarize with scope management plan that outlines how scope will be defined, validated, and controlled.* *To familiarize with schedule management plan that outlines how the project schedule will be developed, monitored, and controlled.*	**9-11**
	Contents: Planning scope management, Collecting requirements, Defining and validating scope, Work breakdown structure (WBS), Scope control Planning schedule management, Defining and sequencing activities, Estimating activity durations, Developing and controlling schedules, Gantt charts	
	Learning Outcomes : *A learner will be able to* *LO2.1: Identify the processes involved in planning scope management and collecting project requirements. (P.I. -2.1.3)* *LO2.2: Identify, assemble and evaluate information and resources to construct a detailed scope management plan that includes processes for scope definition, validation, and control. (P.I.- 2.1.2)* *LO2.3: Apply concept of work breakdown structure (WBS) to manage project completion effectively. (P.I.- 1.3.1)* *LO2.4: Apply laws of natural science to develop, monitor, and control a project schedule management plan that supports effective decision-making and problem-solving throughout the project lifecycle. (P.I.- 1.2.1)*	
03.	**Project Planning and Execution**	**9-11**
	Learning Objective: *To gain the expertise required to draft comprehensive project plans that include budgets, schedules, resource allocations, and risk management strategies.*	

	Contents: Planning and executing projects: Resource loading and levelling, Goldratt's critical chain, Planning monitoring and controlling cycle, information needs and reporting, engaging with all stakeholders of the projects, Team management, Project auditing Risk management in projects: Risk management planning, risk identification and risk register ***Learning Outcomes :*** *A learner will be able to* *LO3.1: Identify and allocate resources effectively to ensure project success. (P.I.- 2.2.2)* *LO3.2: Identify information needs and prepare appropriate reporting structures. (P.I.- 2.1.2)* *LO3.3: Elicit and document planning–monitoring–controlling techniques to track project performance. (P.I.- 3.2.2)* *LO3.4: Determine mitigation strategies and develop a comprehensive risk response plan. (P.I.- 3.1.6)*	
04.	**Project Management in Supply Chains** ***Learning Objective:*** *To acquaint with the project management tools and techniques to manage supply chain projects effectively.* **Contents:** Project planning and scheduling techniques, Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT), Resource allocation and project control ***Learning Outcomes :*** *A learner will be able to* *LO4.1: Identify the project goals with overall supply chain objectives. (P.I. 2.1.2, P.I.- 10.3.1)* *LO4.2: Identify and interpret project activity durations and paths. (P.I. 2.1.3)* *LO4.3: Build project networks and compute critical paths using CPM techniques. (P.I. 3.2.2)* *LO4.4: Apply sequence project activities logically using tools such as network diagrams and dependency determination techniques. (P.I. 3.3.1, P.I. 10.3.2)*	**11-13**
05.	**Cost Management and Communication Management** ***Learning Objectives:*** *To recognize significance of cost management in project and business management contexts.* *To communicate management plan that outlines communication objectives, strategies, channels and frequency.* **Contents:** Planning cost management, Estimating costs, Determining budgets, Cost control and Earned Value Management (EVM) Planning communications management, Managing and controlling communications, Information distribution and reporting, Communication tools and techniques, Planning human resource management, Developing and managing project teams, Leadership and team dynamics ***Learning Outcomes :*** *A learner will be able to* *LO5.1: Apply fundamental concepts and principles of cost management within the context of projects or organizational operations. (P.I. 1.3.1, P.I.- 10.1.1)* *LO5.2: Apply earned value management (EVM) technique to assess cost performance against planned budgets. (P.I. 3.3.1, P.I.- 10.2.1)* *LO5.3: Recommend corrective actions based on cost deviations and performance indices. (P.I. 3.4.2, P.I.- 9.1.1)* *LO5.4: Monitor the effectiveness of communication strategies and channels throughout the project lifecycle while demonstrating leadership practices that promote clarity, alignment, and team engagement. (P.I. 1.2.1, P.I. 8.1.2, P.I.- 8.2.1 P.I.- 9.2.1)*	**11-13**

06.	**Global Supply Chain Management** ***Learning Objective:*** *To acquaint with global supply chain management and its significance in today's interconnected global economy.* **Contents:** Introduction, Supply chain network, Supply chain ecosystem, Supply chain design, Risks in global supply chain management ***Learning Outcomes :*** *A learner will be able to* *LO6.1: Apply foundational knowledge to understand global supply chain concepts (P. I. 1.3.1).* *LO6.2: Apply scientific principles to optimize energy use, material flow, and resource efficiency in supply chain operations. (P. I. 1.2.1).* *LO6.3: Engage in lifelong learning practices to identify, define, and refine understanding of complex supply chain problems in a dynamic environment (P.I. 2.1.1, P.I. 11.2.2).* *LO6.4: Continuously update analytical skills to examine functional interactions across the supply chain, considering changes in the ecosystem and supply chain design (P.I. 2.2.2, P.I. 11.3.2).*	**5-7**
	Course Conclusion	**01**
	Total	**60**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.2.1	Apply laws of natural science to an engineering problem.
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.1	Articulate problem statements and identify objectives.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem.
2.2.2	Identify, assemble and evaluate information and resources.
3.1.6	Determine design objectives, functional requirements and arrive at specifications.
3.2.2	Build models/prototypes to develop a diverse set of design solutions.
3.3.1	Apply formal decision-making tools to select optimal engineering design solutions for further
3.4.2	Generate information through appropriate tests to improve or revise the design.
7.1.1	Identify situations of unethical professional conduct and propose ethical alternatives.
7.2.2	Examine and apply moral & ethical principles to known case studies.
8.1.2	Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.
8.2.1	Demonstrate effective communication, problem-solving, conflict resolution and leadership skills.
9.1.1	Read, understand and interpret technical and non-technical information.
9.2.1	Listen to and comprehend information, instructions, and viewpoints of others.
10.1.1	Describe various economic and financial costs/benefits of an engineering activity.
10.2.1	Analyze and select the most appropriate proposal based on economic and financial considerations.
10.3.1	Identify the tasks required to complete an engineering activity, and the resources required to
10.3.2	Use project management tools to schedule an engineering project, so it is completed on time and on
11.2.2	Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field.
11.3.2	Analyze sourced technical and popular information for feasibility, viability, sustainability, etc.

Course Outcomes: Learner will be able to

1. Apply project management concepts, principles, and terminology and their application within supply chain management. (*LO1.1, LO1.2, LO1.3, LO1.4*)
2. Develop comprehensive project plans that integrate supply chain considerations, timelines and resource requirements. (*LO2.1, LO2.2, LO2.3, LO2.4, LO3.1, LO3.2, LO3.3, LO3.4*)
3. Apply scheduling techniques to supply chain management project activities to improve resource allocation, manage task dependencies, and meet project deadlines. (*LO4.1, LO4.2, LO4.3, LO4.4*)
4. Implement cost management concepts and collaborate and communicate effectively both within project teams and across supply chain stakeholders. (*LO5.1, LO5.2, LO5.3, LO5.4*)
5. Illustrate supply chain strategies and tactics to capitalize on emerging opportunities and mitigate risks in global markets. (*LO6.1, LO6.2, LO6.3, LO6.4*)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCSC703.1	3	3	--	--	--	--	3	--	--	--	--
HMCSC703.2	3	3	3	--	--	--	--	--	--	--	--
HMCSC703.3	--	3	3	--	--	--	--	--	--	3	--
HMCSC703.4	3	--	3	--	--	--	--	3	3	3	--
HMCSC703.5	3	3	--	--	--	--	--	--	--	--	3
Average	**3**	**3**	**3**	**--**	**--**	**--**	**3**	**3**	**3**	**3**	**3**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. "Project Management: A Systems Approach to Planning, Scheduling, and Controlling" by Harold Kerzner, 12th Edition, Wiley.
2. "A Guide to the Project Management Body of Knowledge (PMBOK Guide)" by Project Management Institute, 6th Edition, Project Management Institute.

Reference Books :

1. "Supply Chain Management: Strategy, Planning, and Operation" by Sunil Chopra and Peter Meindl, 6th Edition, Pearson.

Other Resources :

1. NPTEL Course: ‘Project Management’ by Prof. Ramesh Anbanandam, Department of Management Studies, IIT Roorkee.
   Web link- https://onlinecourses.nptel.ac.in/noc24_mg01/preview
2. NPTEL Course: ‘Project Management’ by Prof. Raghu Nandan Sengupta, Department of Industrial and Management Studies, IIT Kanpur.
   Web link- https://onlinecourses.nptel.ac.in/noc19_mg30/preview
3. NPTEL Course: ‘Project management for managers’ by Prof. Mukesh Kumar Barua, Department of Management Studies, IIT Roorkee.
   Web link- https://onlinecourses.nptel.ac.in/noc22_mg71/preview

IN-SEMESTER ASSESSMENT (50 MARKS)

1. **Continuous Assessment (20 Marks)**

Suggested breakup of distribution

Assignment on case studies	:	10 Marks
Open book test/ Open notes test	:	05 Marks
Attendance and active participation	:	05 Marks

2. **Mid Semester Exam (30 Marks)**

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20% - 30% weightage, and the syllabus covered from MSE to ESE carrying 70% - 80% weightage.

Course Type	Course Code	Course Name	Credits
HML	HMLSC701	LOGISTICS SUPPLY CHAIN MANAGEMENT LABORATORY	02

Examination Scheme		
Continuous Assessment	**End Semester Exam (ESE)**	**Total**
50	--	50

Pre-requisite :

1. HMCSC501 - Fundamentals of Logistics Management
2. HMCSC602 - Operations and Supply Chain Management
3. HMCSC703 - Project Management in Supply Chain

Program Outcomes addressed :

1. PO1 - Engineering Knowledge
2. PO2 - Problem Analysis
3. PO3 - Design/Development of Solutions
4. PO5 - Engineering Tool Usage
5. PO9 - Communication
6. PO10 - Project Management and Finance
7. PO11 - Life-Long Learning

Course Objectives:

1. Enable students to apply theoretical principles of logistics and supply chain management in practical scenarios.
2. Provide students with experience in using software tools, simulations, and case studies to model, analyse, and optimize supply chain processes.
3. Develop students' ability to identify real-world supply chain challenges, analyse data, and make informed decisions.

Module	Detailed Contents	Hrs
	Course Introduction This lab provides hands-on experience in supply chain operations through simulations and roleplay, focusing on performance measures, costs, and operational decision-making. Students also explore modern technologies like machine learning, blockchain, and IoT to optimize supply chain efficiency.	**01**
01.	***Learning Objective/s:*** *To analyze real-world supply chain coordination challenges using simulation-based case studies for better decision-making.*	**05**
	Case Study:	
	To analyze coordination challenges in a multi-stage beverage supply chain using the BeverageCo roleplay and propose actions to improve overall system performance.	

	Self-Learning Topics: --- ***Learning Outcomes :*** *A learner will be able to* *LO 1.1: Analyze coordination issues in a multi-stage beverage supply chain using mathematical techniques and roleplay simulation; interpret system-generated performance data; and develop or adapt SCM models/tools to represent supply chain behaviour, evaluate their limitations, and support informed decision-making. (P.I. - 1.1.1, 1.3.1, 5.1.2, 5.2.1, 9.1.1, 9.1.2)*	
02.	***Learning Objective/s:*** *To analyze inventory-related challenges using simulation-based case studies for optimizing inventory decision-making.* **Case Study:** To compute and evaluate major inventory-related costs in an auto-parts warehouse and recommend cost-optimizing inventory decisions. ***Self-Learning Topics:*** --- ***Learning Outcomes :*** *A learner will be able to* *LO 2.1: Analyse and model warehouse inventory cost–performance trade-offs using mathematical and engineering principles; assemble and evaluate required data; apply decision-making tools to select cost-optimizing strategies; and develop or adapt SCM/Excel/Python models to interpret system-generated cost metrics, assess tool limitations, and support financially sound inventory planning. (P.I. - 1.1.1, 1.3.1, 2.2.2, 2.3.1, 3.1.1, 3.3.1, 5.1.2, 5.2.1, 9.1.1, 9.1.2, 10.1.1, 10.2.1)*	**08**
03.	***Learning Objective/s:*** *To analyze lost sales challenges using simulation-based case studies for reduction in mismatch.* **Case Study:** To assess the impact of lost sales in the ElectroMart retail supply chain and determine strategies to reduce demand-supply mismatches. ***Self-Learning Topics:*** --- ***Learning Outcomes :*** *A learner will be able to* *LO 3.1: Analyze lost-sales impacts on service level and supply chain performance using scientific and engineering principles; design improvement strategies to reduce demand–supply mismatches; apply decision-making tools to interpret simulation outputs and evaluate financial implications; and develop or adapt SCM/Excel/Python models to interpret lost-sales metrics, assess tool limitations, and support data-driven mitigation decisions. (P.I. – 2.2.2, 2.3.1, 3.1.1, 3.3.1, 5.1.2, 5.2.1, 9.1.1, 9.1.2, 10.1.1, 10.2.1)*	**08**
04.	***Learning Objective/s:*** *To analyze shortage management using simulation-based case studies for improved service.* **Case Study:** To evaluate shortage situations in a food distribution network and develop effective shortage-management strategies to improve service levels. ***Self-Learning Topics:*** ---	**08**

	Learning Outcomes : *A learner will be able to* *LO 4.1: Analyze and design shortage-management strategies using scientific and engineering principles; apply decision-making tools to evaluate feasible improvements and financial implications; and develop or adapt SCM/Excel/Python models to interpret shortage-related metrics, assess tool limitations, and support data-driven recommendations for enhancing supply chain resilience. (P.I. – 2.2.2, 2.3.1, 3.1.1, 3.3.1, 5.1.2, 5.2.1, 5.3.1, 9.1.1, 9.1.2)*	
05.	***Learning Objective/s:*** *To analyze supply chain performance by studying backorders across diverse industry scenarios.* **Case Study:** To analyze the causes and effects of backorders in a pharma distribution network and recommend strategies to minimize stockouts and improve service levels. ***Self-Learning Topics:*** --- ***Learning Outcomes :*** *A learner will be able to* *LO 5.1: Analyze backorder behaviour in a pharma distribution system by identifying sources of error and applying engineering principles to interpret service-level and inventory impacts; evaluate stockout-reduction proposals; and interpret technical/non-technical information to prepare structured, data-driven reports that assess economic implications and support managerial decision-making. (P.I. - 1.1.1, 1.3.1, 2.4.1, 2.4.3, 9.1.1, 9.1.2, 10.1.1, 10.2.1)*	**08**
06.	***Learning Objective/s:*** *To analyze supply chain performance by studying information-sharing effects across diverse industry scenarios.* **Case Study:** To examine how demand information sharing influences forecast accuracy in fashion retail and propose methods to improve responsiveness and inventory planning. ***Self-Learning Topics:*** --- ***Learning Outcomes :*** *A learner will be able to* *LO 6.1: Apply engineering mathematics and system-dynamics principles to model retail supply-chain flows and assess the impact of demand information sharing on forecast accuracy; develop or adapt analytical tools to evaluate forecasting patterns and feedback delays; identify tool limitations; and interpret coordination issues arising from information-sharing gaps. (P.I. - 1.1.1, 1.1.2, 2.3.1, 2.4.1, 5.1.2, 5.2.1, 9.1.1, 9.1.2)*	**08**
07.	***Learning Objective/s:*** *To analyze supply chain performance by studying system-dynamics coordination issues across diverse industry scenarios.* **Case Study:** To model coordination challenges in a multi-echelon mega-mart supply chain using system dynamics and identify leverage points for improving overall performance. ***Self-Learning Topics:*** ---	**08**

	Learning Outcomes : *A learner will be able to* *LO 7.1: Apply mathematical and engineering principles to compute and interpret key financial and operational indicators in a multi-echelon supply chain; and prepare structured system-dynamics analyses that generate clear, data-driven insights on coordination challenges, economic implications, and the suitability of improvement strategies for managerial decision-making. (P.I. - 1.1.1, 1.3.1, 9.1.1, 9.1.2, 10.1.1, 10.2.1)*	
08.	***Learning Objective/s:*** *To understand supply chain performance by studying the role of emerging technologies across diverse industry scenarios.* **Case Study:** To evaluate the role of emerging technologies (IoT, blockchain, sensors, AI) in enhancing visibility and reducing losses in fresh-farm perishable supply chains. ***Self-Learning Topics:*** --- ***Learning Outcomes :*** *A learner will be able to* *LO 8.1: Create or adapt analytical tools to evaluate emerging technologies such as IoT, blockchain, and AI for perishable supply chains; assess feasibility, impact, and tool limitations; stay current with technological developments; and prepare structured, data-driven analyses that interpret technical information, examine economic implications, and evaluate the suitability of technology-enabled improvement strategies for managerial decision-making. (P.I. - 5.1.2, 5.3.1, 9.1.1, 9.1.2, 10.1.1, 10.2.1, 11.2.2, 11.3.2)*	**06**
	Total	**60**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems.
1.1.2	Apply advanced mathematical techniques to model and solve mechanical engineering problems
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
2.2.2	Identify, assemble and evaluate information and resources.
2.3.1	Combine scientific principles and engineering concepts to formulate models of a system or process.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
2.4.3	Identify sources of error in the solution process and limitations of the solution.
3.1.1	Identify design requirements and constraints to develop feasible engineering solutions.
3.3.1	Evaluate systems and processes to meet desired needs.
5.1.2	Create, adapt, modify, or extend tools and techniques to solve engineering problems.
5.2.1	Identify the strengths and limitations of tools for modeling and simulating engineering systems.
5.3.1	Discuss limitations and validate tools, techniques, and resources with respect to assumptions and accuracy.
9.1.1	Communicate effectively with clarity in oral, written, and graphical forms.
9.1.2	Prepare and present structured technical documents/reports aligned with engineering requirements.
10.1.1	Apply management principles to estimate cost, resources, and scheduling needs.
10.2.1	Analyze and interpret financial/operational performance indicators for decision-making.

11.2.2 Identify gaps in existing knowledge and demonstrate the ability to acquire new skills independently.

11.3.2 Analyze sourced technical information for feasibility, viability, and sustainability.

Course Outcomes: A learner will be able to…….

1. Apply fundamental supply chain management concepts in simulations and cost-modelling. *(LO 1.1, LO 2.1)*
2. Identify and interpret supply-chain performance under lost sales, shortages and supply-demand mismatch parameters. *(LO 3.1, LO 4.1)*
3. Assess the coordination problems between supply chain backorders, forecast errors and information sharing issues. *(LO 5.1, LO 6.1)*
4. Analyze the need for effective supply chain management using system dynamics concepts. *(LO 7.1)*
5. Evaluate analytical tools and emerging technologies for supply-chain improvement. *(LO 8.1)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMLSC701.1	3	3	3	--	3	--	--	--	3	3	--
HMLSC701.2	--	3	3	--	3	--	--	--	3	3	--
HMLSC701.3	3	3	--	--	3	--	--	--	3	3	--
HMLSC701.4	3	--	--	--	--	--	--	--	3	3	--
HMLSC701.5	--	--	--	--	3	--	--	--	3	3	3
Average	**3**	**3**	**3**	**--**	**3**	**--**	**--**	**--**	**3**	**3**	**3**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Chopra, S. & Meindl, P. *Supply Chain Management: Strategy, Planning, and Operation.* Pearson.
2. Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. *Designing and Managing the Supply Chain.* McGraw Hill.

Reference Books:

1. Stadtler, H. *Supply Chain Management and Advanced Planning.* Springer.
2. Hugos, M. H. *Essentials of Supply Chain Management.* Wiley.

Other Resources :

1. Supply Chain Roleplay Game Simulation Software (e.g., Beer Distribution Game Simulator, SCM Globe, or custom SCM roleplay platform)
2. Microsoft Excel / Python for Data Analysis
3. System Dynamics tools (Vensim / Stella)
4. ML & Blockchain Visualization Demos

5. MIT Beer Game: https://beergame.mit.edu/
6. SCM Globe: https://www.scmglobe.com/

IN-SEMESTER ASSESSMENT (50 MARKS)

Continuous Assessment (50 Marks)

Performance based on case-studies and assignments	:	20 Marks
Oral conducted during the practical performance	:	05 Marks
Course Project *(group of 3 students only)*	:	20 Marks
Regularity and Active Participation	:	05 Marks

Course Type	Course Code	Course Name	Credits
HMC	HMCSC804	QUALITY MANAGEMENT IN SUPPLY CHAIN	04

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. HMCSC501 - Fundamentals of Logistics Management

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/Development of Solutions
4. PO4: Conduct investigations of complex problems
5. PO5: Engineering Tool Usage
6. PO9: Communication
7. PO11: Life-long learning

Course Objectives:

1. To become familiar with quality management concept.
2. To know the role of quality management in logistics and supply chain.
3. To comprehend how quality management tools and techniques are applied specifically within the context of supply chain.
4. To acquaint with supplier quality management and various performance measurements.

Module	Details	Hrs
	Course Introduction The course "Quality Management in Logistics and Supply Chain" is intended to give students with the fundamental information and skills required to effectively manage quality within a supply chain. This course focuses on the international quality systems, which are applicable to supply chains and attracting the attention of the global competitive businesses that aim to implement these methods in the most efficient way. This course is designed to introduce to the theory and practice of quality management to develop the skills, to apply the tasks and techniques to the continuous improvement initiatives in the workplace. In the first part, the course covers conceptual principles of quality management, possible barriers to effective quality management and control. Following that, the course is focused on techniques for quality management systems, tools and	**01**

	techniques in quality management systems. The last part of the course deals with quality metrics and performance evaluations.	
01.	**Introduction to Quality Management** ***Learning Objective:*** *To enable learners understand and apply the fundamental principles of quality management.* **Contents:** Definition and importance of quality, Evolution of quality, Product and service quality, Dimensions of quality; Need for quality management, Costs of quality, Barriers for implementation of quality management. Contributions of quality gurus: Deming, Juran, Crosby, Feigenbaum, Ishikawa and Taguchi, Juran Trilogy, PDCA Cycle ***Learning Outcomes :*** *A learner will be able to* *LO1.1: Apply fundamental engineering to interpret the definition, evolution, and importance of quality in product and service systems (P.I.- 1.3.1)* *LO1.2: Apply scientific principles to understand the concept of the costs of quality in supply chain (P.I.- 1.2.1)* *LO1.3: Identify barriers influencing quality management implementation (P.I.- 2.1.2)* *LO1.4: Analyze and evaluate the Juran Trilogy to determine root causes of quality issues in engineering and supply chain environments (P.I.- 2.2.2)* *LO1.5: Design project management framework using PDCA cycle for continuous improvement (P.I.- 3.2.2)* *LO1.6: Apply quality improvement strategies using principles from quality gurus and continuous improvement frameworks (P.I.-3.3.1)*	**7-9**
02.	**Quality Management Systems and Standards** ***Learning Objective:*** *To inculcate the concept of quality management systems and standards.* **Contents:** Introduction, Benefits of ISO registration, ISO 9000 series of standards, ISO 9001 requirements, implementation, documentation and quality auditing ***Learning Outcomes :*** *A learner will be able to* *LO2.1: Apply engineering fundamentals to understand quality standards (P.I.- 1.3.1)* *LO2.2: Apply scientific approach to understand the structure of ISO 9000 family of standards in QMS processes (P.I.- 1.2.1)* *LO2.3: Recognize organizational needs for QMS design (P.I. - 3.1.1)* *LO2.4: Apply ISO 9001 requirements to design and document a compliant QMS (P.I. - 3.2.2 P.I.-5.1.1, P.I.-5.1.2)* *LO2.5: Identify suitable criteria to evaluate QMS documentation formats (P.I. - 3.2.3)*	**7-9**
03.	**Quality Management Tools and Control Charts** ***Learning Objective:*** *To acquaint with the quality management tools and control charts to manage quality in logistics and supply chain effectively.* **Contents:** Seven QC Tools: Check sheet, Histogram, Pareto chart, Fishbone diagram, Run charts, Scatter diagram, Process flow chart Variations concept, random & assignable causes, Control charts, X-Bar, R, P and C Charts ***Learning Outcomes:*** *A learner will be able to* *LO3.1: Apply engineering fundamentals to understand data-driven quality tools. (P.I.- 1.3.1)*	**11-13**

	LO3.2: Apply scientific approach to identify more appropriate tools for quality management. (P.I.- 1.2.1) *LO3.3: Analyze data in quality check of product/services to understand correlations in parameters and interpret the information (P.I.- 4.3.2, P.I.- 9.1.1)* *LO3.4: Represent data using various types of control charts (P.I.- 4.3.3, P.I. 9.3.2)*	
04.	**Continuous Process Improvement** ***Learning Objective:*** *To acquaint with concepts of continuous improvement processes.* **Contents:** Quality circles, Quality Function Deployment (QFD), Taguchi quality loss function, TPM- concepts, 5S, Kaizen, FMEA- stages, Zero defect Introduction to Six Sigma: Definition, Concept, Methodology Six Sigma Approaches: Design for Six Sigma (DFSS) & DMAIC ***Learning Outcomes :*** *A learner will be able to* *LO4.1: Apply engineering knowledge and analytical tools to evaluate quality improvement techniques (P.I.- 1.3.1)* *LO4.2: Apply Taguchi loss function a statistical technique to quantify the economic loss in product/process (P.I. 1.1.1)* *LO4.3: Identify systems, variables, parameters in QC/QFD/TPM/FMEA for continuous improvement. (P.I.- 2.1.2, P.I.- 11.1.1)* *LO4.4: Identify and analyze data to identify causes for process improvement (DFSS and DMAIC) (P.I.- 2.1.3, P.I.- 11.1.2)*	**11-13**
05.	**Supplier Quality Management and IT in Quality Management** ***Learning Objectives:*** *To know the concept of supplier quality management.* *To grasp the necessity of information technology in quality management.* **Contents:** Importance of supplier quality management, Supplier selection and evaluation, Supplier development and relationship management Role of information technology in quality management, Quality management software and tools, Supply chain visibility and traceability ***Learning Outcomes :*** *A learner will be able to* *LO5.1: Identify various evaluation methods for supplier selection. (P.I.- 2.2.3, P.I.- 11.2.1)* *LO5.2: Apply scientific principles for fostering strong supplier relationships (collaboration, communication, long-term contracts) (P.I.- 1.2.1)* *LO5.3: Apply fundamentals of IT engineering to improve data accuracy, decision-making, and process efficiency (P.I.- 1.3.1)* *LO5.4: Identify the role and necessity of IT in quality management. (P.I.- 2.2.2, P.I.- 11.2.2, P.I.- 11.3.2)*	**7-9**
06.	**Quality Metrics and Performance Measurement** ***Learning Objective:*** *To acquaint with various performance measurement for quality management.* **Contents:** Key performance indicators (KPIs) for quality management, Balanced scorecard approach to quality measurement, Benchmarking and best practices. Quality awards: Malcom Baldrige National Quality award, Deming Prize award, European Foundation for Quality Management (EFQM) award; and Rajiv Gandhi National Quality award ***Learning Outcomes :*** *A learner will be able to* *LO6.1: Recognize relevant KPIs for quality management (P.I.- 3.1.1)* *LO6.2: Identify best practices from award-winning organizations into organizational processes (P.I.- 2.2.3).*	**9-11**

	LO6.3: Develop scorecard to measure the quality of systems for potential recognition (P.I.- 3.2.1). *LO6.4: Identify industry best practices and compare with organizational processes. (P.I.- 2.2.4).*	
	Course Conclusion	**01**
	Total	**60**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems
1.2.1	Apply laws of natural science to an engineering problem
1.3.1	Apply fundamental engineering concepts to solve engineering problems
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
2.2.2	Identify, assemble and evaluate information and resources.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions
2.2.4	Compare and contrast alternative solution processes to select the best process.
3.1.1	Recognize that need analysis is key to good problem definition
3.2.1	Apply formal idea generation tools to develop multiple engineering design solutions
3.2.2	Build models/prototypes to develop a diverse set of design solutions
3.2.3	Identify suitable criteria for the evaluation of alternate design solutions
3.3.1	Apply formal decision-making tools to select optimal engineering design solutions for further development
4.3.2	Analyze data for trends and correlations, stating possible errors and limitations
4.3.3	Represent data (in tabular and/or graphical forms) so as to facilitate analysis and explanation of the data, and drawing of conclusions
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling and analysis; techniques and resources for engineering activities
5.1.2	Create/adapt/modify/extend tools and techniques to solve engineering problems
9.1.1	Read, understand and interpret technical and non-technical information
9.3.2	Use a variety of media effectively to convey a message in a document or a presentation.
11.1.1	Describe the rationale for the requirement for continuing professional development
11.1.2	Identify deficiencies or gaps in knowledge and demonstrate an ability to source information to close this gap
11.2.1	Identify historic points of technological advance in engineering that required practitioners to seek education in order to stay current.
11.2.2	Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field.
11.3.2	Analyze sourced technical and popular information for feasibility, viability, sustainability, etc.

Course Outcomes: A learner will be able to

1. Develop an understanding on quality and quality management philosophies. (*LO1.1, LO1.2, LO1.3, LO1.4, LO1.5, LO1.6*)
2. Apply QMS and certification for quality accreditation. (*LO2.1, LO2.2, LO2.3, LO2.4, LO2.5*)
3. Illustrate an ability to utilize data gathering and analysis tools as related to process control and use continuous improvement techniques for process improvement. (*LO3.1, LO3.2, LO3.3, LO3.4, LO4.1, LO4.2, LO4.3, LO4.4*)
4. Illustrate the impact of emerging technologies in IT systems to improve supply chain operations. (*LO5.1, LO5.2, LO5.3, LO5.4*)
5. Identify current trends and benchmark organizations related to Quality Management. (*LO6.1, LO6.2, LO6.3, LO6.4)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCSC804.1	3	3	3	--	--	--	--	--	--	--	--
HMCSC804.2	3	--	3	--	3	--	--	--	--	--	--
HMCSC804.3	3	3	--	3	--	--	--	--	3	--	3
HMCSC804.4	3	3	--	--	--	--	--	--	--	--	3
HMCSC804.5	--	3	3	--	--	--	--	--	--	--	--
Average	**3**	**3**	**3**	**3**	**3**	--	--	--	**3**	--	**3**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. 'Total Quality Management' by D. H. Besterfield, 3rd Edition, Pearson Education.
2. 'Total Quality Management' by B. Janakiraman and R. K. Gopal, 1st Edition, Prentice Hall India.
3. 'Total Quality Management' by P. M. Charantimath, 2nd Edition, Pearson Education Asia.

Reference Books :

1. 'The Management and Control of Quality' by James R. Evans and William M. Lindsay, 6th Edition, South-Western (Thomson Learning).
2. 'TQM - Text with Cases' by J. S. Oakland, Butterworth – Heinemann Ltd., 3rd Edition, Oxford.

Other Resources :

1. NPTEL Course: 'Total Quality Management - I' by Prof. Raghu Nandan Sengupta, Department of Management Studies, IIT Kanpur.
   Web link- https://nptel.ac.in/courses/110104080
2. NPTEL Course: 'Total Quality Management - II' by Prof. Raghu Nandan Sengupta, Department of Management Studies, IIT Kanpur.
   Web link- https://nptel.ac.in/courses/110104085

IN-SEMESTER ASSESSMENT (50 MARKS)

1. **Continuous Assessment (20 Marks)**

Suggested breakup of distribution

Assignment on case studies	:	10 Marks
One MCQ test as per GATE exam pattern/level	:	05 Marks
Attendance and active participation	:	05 Marks

2. **Mid Semester Exam (30 Marks)**

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
HMP	HMPSC801	Honours/Minor Mini Project	02

Program Outcomes addressed:

1. PO1 : Engineering knowledge
2. PO2 : Problem Analysis
3. PO3 : Design/Development of Solutions
4. PO4 : Conduct investigations of complex problems
5. PO5 : Modern Tool Usage
6. PO6 : The Engineer & World
7. PO7 : Ethics
8. PO8 : Individual & team work
9. PO9 : Communication
10. PO10: Project Management & Finance
11. PO11: Life-long learning

Course Objectives

1. To guide students in identifying specialization-domain problems
2.. To explore advanced solutions using emerging technologies and specialized tools.
3. To develop research aptitude, innovation mindset, entrepreneurship potential, and lifelong learning skills.
4.. To foster self-directed learning, domain-specific competency, and collaboration.

Course Outcomes

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

CO1: Identify and articulate a domain-relevant societal, industrial, or research problem using literature review and analysis.

CO2: Apply engineering principles and specialized tools to design innovative and feasible technical solutions.

CO3: Conduct investigations, simulations, or experiments to validate the proposed solution using appropriate methods.

CO4: Evaluate the solution considering sustainability, ethics, feasibility, and potential for commercialization or IP.

CO5: Demonstrate teamwork, project management, and professional technical communication through reports and presentations.

CO6: Engage in self-directed learning and continuous improvement to enhance domain expertise and professional growth.

Guidelines for the Mini Project

• Projects should align with the Honors/Minor specialization domain
Mini project may be carried out in one or more form of following:
Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software development, integration of software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc.
• Students must form groups of 3 to 4 members.

- **Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty.**
- **An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted.**
- **Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor.**
- **Faculty input should emphasize guiding by faculty and self-learning by group members.**
- **Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model.**
- **The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report.**
- **With the focus on self-learning, innovation, research orientation, addressing societal and industry challenges, and developing entrepreneurship qualities among students, the Mini Project should reflect appropriate depth, technical sophistication, specialization-domain relevance, and quality. Students are encouraged to adopt an innovative approach, explore emerging technologies, and demonstrate prototype development, domain-specific research outputs, or commercialization potential, rather than limiting to basic model implementation.**

In-Semester Continuous Assessment and End-Semester Examination Guidelines

- **The coordinating Head of the Department will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations in a semester.**
- **Assessment will be based on individual contributions, understanding, and responses to questions asked.**
- **Continuous Assessment marks distribution (50 marks):**
    - **20 marks for the Topic Approval Presentation in front of the progress monitoring committee**
    - **20 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee**
    - **10 marks for regularity & active participation**

The review/progress monitoring committee will assess projects based on the following criteria.

- **Theoretical solution completion, including component/system selection/design of software solution and cost analysis.**
- **Two reviews will occur:**
    - **The first review will focus on finalizing the problem statement (topic approval).**
    - **Second review will assess the progress of building a working prototype. (Mid Semester Presentation)**

In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:

1. **Quality of survey and need identification aligned with specialization or societal/industry relevance.**
2. **Clarity and innovativeness in problem definition and solution Clarity, originality, and innovativeness in problem definition, solution approach, and use of advanced tools/techniques.**
3. **Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.**
4. **Completeness and full functioning of the working model.**
5. **Effective use of skill sets and engineering norms.**
6. **Verification & validation of the solutions/test cases.**
7. **Individual contributions to the group.**
8. **Clarity in written and oral communication.**

9. Participation in research paper presentation, domain-specific competitions, hackathons, demonstrations, start-up pitching, or innovation challenges.

End-Semester Examination (50 marks):

1. **Presentation and demonstration to internal and external examiners: 20 marks.**
2. **Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.**

Curriculum Structure for Honours/Minor Degree Program in 'Aeronautical Engineering'

Course Type	Sem	Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
				L	P	T	L	P	T	Total
HMC	V	HMCAN501	Basics of Aeronautical Engineering	3	--	--	3	--	--	3
HMC	VI	HMCAN602	Low Speed Aerodynamics and Flight Dynamics	3	--	--	3	--	--	3
HMC	VII	HMCAN703	Aircraft Structural Design & Analysis	4	--	--	4	--	--	4
HML	VII	HMLAN701	Aero-modeling and Simulation Laboratory	--	4	--	--	2	--	2
HMC	VIII	HMCAN804	Aircraft Control Systems	4	--	--	4	--	--	4
HMP	VIII	HMPAN801	Mini Project	--	6	--	--	2	--	2
Total				**14**	**10**	**--**	**14**	**04**	**--**	**18**

Examination Scheme for Honours/Minor Degree Program in 'Aeronautical Engineering'

Course Type	Sem	Course Code	Course Name	In-Semester Assessment		End Sem Exam (ESE)	Exam duration for Theory (in Hrs)		
				Continuous Assessment	Mid Sem Exam		Mid Sem	End Sem	Total
HMC	V	HMCAN501	Basics of Aeronautical Engineering	20	30	50	1.5	2	100
HMC	VI	HMCAN602	Low Speed Aerodynamics and Flight Dynamics	20	30	50	1.5	2	100
HMC	VII	HMCAN703	Aircraft Structural Design & Analysis	20	30	50	1.5	2	100
HML	VII	HMLAN701	Aero-modeling and Simulation Laboratory	50	--	--	--	--	50
HMC	VIII	HMCAN804	Aircraft Control Systems	20	30	50	1.5	2	100
HMP	VIII	HMPAN801	Mini Project	50	--	--	--	--	50
Total				**180**	**120**	**250**	**--**	**--**	**550**

Course Type	Course Code	Course Name	Credits
HMC	HMCAN703	AIRCRAFT STRUCTURAL DESIGN AND ANALYSIS	04

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. ESC101 - Engineering Mechanics
2. MEPCC302 - Mechanics of Solids
3. HMCAN501 - Basics of Aeronautical Engineering

Program Outcomes addressed :

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/Development of Solutions
4. PO4: Conduct Investigations of Complex Problems
5. PO8: Individual and Collaborative Team work
6. PO9: Communication
7. PO11: Life-Long Learning

Course Objectives :

1. Introduce the phases of aircraft design and their structural implications.
2. Familiarize students with wing, tail, and fuselage geometry selection and structural layout.
3. Develop skills for sizing and lofting of fuselage, wing, and control surfaces.
4. Study integration of landing gear and subsystems.
5. Analyze structural instability phenomena such as buckling and crippling.
6. Perform stress analysis of wing and fuselage structures under flight loads.

Module	Details	Hrs.
	Course Introduction This course provides a comprehensive understanding of the aircraft design process, from conceptual design to detailed analysis of structures and systems. Students will learn methods for estimating aircraft weights, selecting and designing airfoils, and determining wing and tail geometry. The course covers sizing of engines, fuselage, wings, and control surfaces, as well as development of configuration layouts and lofting techniques. Integration of propulsion, landing	**01**

	gear, and subsystems is emphasized, alongside structural analysis including buckling of plates and stress distribution in wings and fuselage. By combining theoretical concepts with practical design procedures, the course equips students with the skills to perform preliminary and detailed aircraft design effectively.	
01.	**Phases of Aircraft Design** ***Learning Objective/s:*** 1. *To differentiate and outline the phases of aircraft design, including conceptual, preliminary, and detailed design processes.* 2. *To apply conceptual sizing methods for take-off weight build-up, empty weight estimation, fuselage fraction estimation, and overall take-off weight calculation.*	**8-10**
	Contents: Introduction to Conceptual Design, Preliminary Design and Detailed Design concepts, Sizing from a conceptual Design, Take-off Weight Build up, Empty Weight Estimation, Fuselage Fraction Estimation, Take-off weight Calculation	
	Self-Learning Topics: *Empirical weight estimation formulas and statistical methods used in preliminary aircraft design.*	
	Learning Outcomes : *A learner will be able to* *LO 1.1 apply fundamental engineering and mathematical relationships to estimate take-off weight, empty weight and fuselage fractions in the early design stages. (PI 1.3.1)* *LO 1.2 Utilize core aerospace engineering principles to explain conceptual, preliminary and detailed design workflows. (PI 1.4.1)* *LO 1.3 Identify the required inputs, constraints and parameters necessary for performing aircraft sizing and weight build-up calculations. (PI 2.1.1)* *LO 1.4 Formulate appropriate analytical models and justified assumptions for estimating aircraft weight fractions and sizing parameters. (PI 2.3.1)* *LO 1.5 Derive design specifications and refine conceptual sizing outputs into preliminary aircraft design estimates within practical engineering constraints. (PI 3.1.6)* *LO 1.6 Evaluate alternative sizing strategies and select the most suitable design configuration for further development. (PI 3.2.1)*	
02.	**Airfoil and Geometry Selection** ***Learning Objective/s:*** 1. *To analyze and compare airfoil characteristics and wing geometry parameters such as aspect ratio, sweep, taper ratio, twist, incidence, dihedral, and vertical location for aerodynamic and structural performance.* 2. *To evaluate and select appropriate tail configurations, geometry, and arrangements (including for spin recovery) based on stability, control, and structural design considerations.*	**8-10**
	Contents: Airfoil selection, Airfoil design, Stall, Design Lift Coefficient, Airfoil thickness ratio, Other airfoil considerations, Wing geometry, Aspect ratio, Wing Sweep, Taper ratio, Twist, Wing Incidence, Dihedral, Wing Vertical Location, Wing Tips, Biplane Wings Tail Geometry and Arrangement, Tail functions, Tail arrangement, Tail arrangement for spin recovery, Tail geometry	

	Self-Learning Topics: *Comparative study of NACA airfoil families and their influence on wing and tail design.*	
	Learning Outcomes : *A learner will be able to* *LO 2.1 Apply aerodynamic principles and mathematical relationships to compute design lift coefficients, aspect ratio effects, stall margins, and airfoil geometry parameters. (PI 1.1.1)* *LO 2.2 Apply the aerodynamic implications of airfoil characteristics, wing geometry parameters, and tail configurations in aircraft design. (PI 1.4.1)* *LO 2.3 Identify design requirements, aerodynamic constraints, and performance considerations necessary for airfoil, wing, and tail selection. (PI 2.1.2)* *LO 2.4 Formulate aerodynamic models and justified assumptions to evaluate lift, stall behavior, stability contributions, and the influence of wing/tail geometry. (PI 2.3.1)* *LO 2.5 Derive wing and tail design specifications and refine airfoil/geometry selections to satisfy stability, lift, and control requirements. (PI 3.4.1)* *LO 2.6 Evaluate alternative wing and tail configurations—including sweep, taper, twist, dihedral, incidence, and tail arrangement for spin recovery—and select an optimal solution for further development. (PI 3.2.1)*	
03.	**Sizing, Configuration Layout and Loft** ***Learning Objective/s:*** *1. Perform sizing of engines, fuselage, wings, and control surfaces using standard methods such as the Tail Volume Coefficient method.* *2. Develop and interpret fuselage and wing/tail layouts using techniques like conic lofting, flat-wrap lofting, airfoil interpolation, and wing/tail cross-section development.*	**9-11**
	Contents: *Sizing:* Engine Sizing, Sizing of fuselage and wing, Tail volume coefficient Method, Control Surface Sizing *Configuration Layout and Loft:* Introduction to configuration layout, End products of configuration layouts, Conic Lofting, Conic Fuselage Development, Flat Wrap Fuselage Lofting, Circle to Square Adapter, Wing/Tail Layout and Loft, Wing location with respect to the Fuselage, Airfoil Linear Interpolation, Airfoil Flat-Wrap Interpolation, Wing/ Tail cross-section layout, Wing Fillets.	
	Self-Learning Topics: *Hands-on Aircraft Component Sizing and 3D Lofting using CAD Tools*	
	Learning Outcomes :	
	A learner will be able to *LO 3.1 Identify design parameters, geometric constraints, and sizing requirements necessary for aircraft configuration layout and lofting. (PI 2.1.2)* *LO 3.2 Formulate analytical and geometric models—including lofting curves, interpolated airfoils, and sizing equations—using appropriate assumptions and principles. (PI 2.3.1)*	

LO 3.3 Derive and refine configuration layout specifications, including fuselage development, wing–tail placement, and lofting contours, to meet performance and stability requirements. (PI 3.4.1)
LO 3.4 Evaluate alternative aircraft configurations and select optimal sizing and layout solutions for detailed design progression. (PI 3.2.1)
LO 3.5 A Task-Based Group Activity Before MSE (Part I)
(PI 8.1.1, PI 8.1.2, PI 8.2.1, PI 9.1.3, PI 9.3.1, PI 11.1.2, PI 11.3.1)

Integrated Conceptual Aircraft Design & Configuration Development Task

Students in teams of maximum 4 must design a preliminary aircraft configuration by completing the following steps:

i. ***Conceptual & Preliminary Design:***
Define the mission, state major design assumptions, and outline the design workflow.

ii. ***Weight Estimation:***
Perform take-off weight build-up, empty weight estimation, fuselage fraction estimation, and finalize the aircraft's take-off weight.

iii. ***Airfoil & Geometry Selection:***
Select suitable wing and tail airfoils; determine wing parameters such as aspect ratio, sweep, taper ratio, twist, incidence, dihedral, wing location, and tail arrangement.

iv. ***Component Sizing:***
Size the engine, fuselage, wing, tail (using tail volume coefficients), and major control surfaces.

v. ***Configuration Layout & Lofting:***
Prepare three-view drawings; develop fuselage lofting using conic or flat-wrap methods; perform airfoil interpolation for root–tip variation; generate wing/tail cross-sections and fillets.

Teams will submit a short report containing calculations, sketches, lofting diagrams, and justifications for all design choices.

04.	**Integration of Systems**	8-10

Learning Objective/s:

1. *Size propellers, estimate engine power, and determine optimal propeller placement.*
2. *Design landing gear arrangements, select tires and shock absorbers, and determine gear geometry and retraction mechanisms.*

Contents:

Propeller Engine Integration, Propeller Sizing, Propeller location, Engine size estimation Landing Gear and subsystems: Landing Gear arrangements, Tire sizing, Shock Absorbers, Types, Stroke determination, Oleo sizing, Solid-spring gear sizing, Castoring wheel geometry, Gear Retraction Geometry.

Self-Learning Topics:
Design and Analysis of Aircraft Propulsion and Landing Gear Systems Using CAD/Simulation Tools

Learning Outcomes :

A learner will be able to

LO 4.1 Apply engineering fundamentals and mathematical relationships to estimate propeller performance, propeller diameter, tire dimensions, shock absorber stroke, and landing gear load characteristics. (PI 1.3.1)

	LO 4.2 Interpret the aerodynamic and structural principles governing propeller–engine integration, landing gear arrangements, shock absorber types, and retraction mechanisms. (PI 1.4.1) *LO 4.3 Identify design requirements, operational constraints, and performance parameters necessary for propeller sizing, engine location, gear placement, and shock absorber selection. (PI 2.1.2)* *LO 4.4 Formulate analytical models and justified assumptions to compute propulsion–airframe interactions, landing gear loads, stroke requirements, and retraction geometry. (PI 2.3.1)* *LO 4.5 Derive design specifications for propeller–engine placement, landing gear configuration, and subsystem geometry, and refine these designs to ensure stability, safety, and performance. (PI 3.4.1)* *LO 4.6 Evaluate alternative propeller locations, engine sizes, landing gear arrangements, shock absorber types, and retraction layouts to select optimal design solutions. (PI 3.3.1)*	
05.	**Buckling of Plates** ***Learning Objective/s:*** 1. *Analyze local buckling, crippling stresses, and column strength in thin-walled sections using standard methods.* 2. *Assess effective width, sheet wrinkling, and failure mechanisms in stiffened panels.*	**10-12**
	Contents: Rectangular sheets under compression, local buckling stress of thin walled sections, crippling stresses by Needham's and Gerard's methods, thin walled column strength. Sheet stiffener panels, Effective width, inter rivet and sheet wrinkling failures.	
	Self-Learning Topics: *Analysis and Design of Thin-Walled Structures Using Numerical and Analytical Methods*	
	Learning Outcomes : *A learner will be able to* *LO 5.1 Apply mathematical and structural fundamentals to compute buckling, crippling, and thin-walled column strength. (PI 1.3.1)* *LO 5.2 Apply fundamentals of buckling behavior, stiffener influence, and failure mechanisms in thin-walled structures. (PI 1.4.1)* *LO 5.3. Identify parameters affecting buckling, crippling, and wrinkling failures. (PI 2.1.2)* *LO 5.4. Formulate models using Needham's, Gerard's, and panel stability methods. (PI 2.3.1)* *LO 5.5 Identify loading conditions, geometric variables, boundary constraints, and failure mechanisms associated with buckling and crippling of sheets and stiffened panels. (PI 4.1.1)* *LO 5.6 Formulate analytical models (Needham's, Gerard's, sheet-stiffener panel equations) and appropriate assumptions to predict buckling and wrinkling behavior. (PI 4.1.2)*	
06.	**Stress Analysis in Wing and Fuselage**	**9-11**
	Learning Objective/s: 1. *Calculate shear and bending moment distributions in wings and fuselage, including thin webbed beams.* 2. *Apply shear-resistant web beams and tension field (Wagner's) web beams in structural design.*	

	Contents: Procedure – Shear and bending moment distribution of wings and fuselage, thin webbed beam. Shear resistant web beams, Tension field web beams (Wagner's). ***Self-Learning Topics:*** *Structural Analysis of Aircraft Wings and Fuselage Using Shear and Bending Moment Calculations.* ***Learning Outcomes :*** *A learner will be able to* *LO 6.1 Identify loading conditions, structural configurations, and failure considerations that influence shear distribution, bending moments, and web-beam behavior. (PI 2.1.2)* *LO 6.2 Formulate analytical models and appropriate assumptions to predict shear flow, tension-field action, and structural response of thin-walled beams. (PI 2.3.2)* *LO 6.3 Derive design requirements for shear-carrying members and refine wing/fuselage beam designs to ensure effective load transfer and structural integrity. (PI 3.1.6)* *LO 6.4 Evaluate alternative web designs—including thin webs, shear-resistant webs, and Wagner tension-field webs—to select the most optimal and weight-efficient structural configuration. (PI 3.2.1)* *LO 6.5 A Task-Based Group Activity After MSE (Part II) (PI 8.1.1, PI 8.1.2, PI 8.2.1, PI 9.1.3, PI 9.3.1, PI 11.1.2, PI 11.3.1)* ***Propulsion–Landing Gear Integration & Structural Behavior Analysis Task*** *Students in teams of maximum 4 must design a preliminary aircraft configuration by completing the following steps:* ***i. Propeller Integration:*** *Estimate required engine power, perform propeller sizing, and justify propeller placement.* ***ii. Landing Gear Selection:*** *Choose a landing gear arrangement and size the tires based on expected loads.* ***iii. Shock Absorber Design:*** *Calculate shock absorber stroke and size an oleo or solid-spring gear.* ***iv. Retraction Layout:*** *Create a simple sketch showing the landing gear retraction geometry.* ***v. Buckling Analysis:*** *Compute local buckling stress and crippling stresses using Needham's and Gerard's methods.* ***vi. Column Strength Evaluation:*** *Determine thin-walled column strength and compute effective width for a stiffened panel.* ***vii. Failure Identification:*** *Identify potential structural failure modes such as wrinkling, inter-rivet buckling, and stiffener failures.* ***viii. Shear–Bending Analysis:*** *Draw shear force and bending moment diagrams for a selected wing or fuselage segment.* ***ix. Web Beam Comparison:*** *Analyze and compare thin-web, shear-resistant web, and tension-field (Wagner) web beam behavior using shear flow calculations.* *Teams will submit a short report containing calculations, sketches, lofting diagrams, and justifications for all design choices.*	
	Course Conclusion	**01**
	Total	**60**

Performance Indicators:

P.I. No.	P.I. Statement
1.1.1	Apply mathematical techniques such as calculus, linear algebra and statistics to solve problems.
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply mechanical engineering concepts to solve engineering problems.
2.1.1	Articulate problem statements and identify objectives.
2.1.2	Identify engineering systems, variables and parameters to solve the problems.
2.3.1	Combine scientific principles and engineering concepts to formulate model(s) (mathematical or otherwise) of a system or process appropriate for applicability and required accuracy.
2.3.2	Identify assumptions (mathematical and physical) necessary to allow modeling of a system at the required accuracy level.
3.1.6	Determine design objectives, functional requirements and arrive at specifications.
3.2.1	Apply formal idea generation tools to develop multiple engineering design solutions.
3.3.1	Apply formal decision-making tools to select optimal engineering design solutions for further development.
3.4.1	Refine a conceptual design into a detailed design within existing resource constraints.
4.1.1	Define a problem, its scope and importance for purposes of investigation.
4.1.2	Examine relevant methods, tools and techniques of experiment design, system calibration, data acquisition, analysis and presentation.
8.1.1	Recognize a variety of working and learning preferences; appreciate the value of diversity on a team.
8.1.2	Implement norms of effective teamwork (rules, roles, agendas, charters) to accomplish a goal.
8.2.1	Demonstrate effective communication, problem–solving, conflict resolution and leadership skills.
9.1.3	Create flow in a document or presentation—logical progression of ideas so that the main point is clear.
9.3.1	Create engineering-standard figures, reports and drawings to complement writing and presentations.
11.1.2	Identify deficiencies or gaps in knowledge and demonstrate ability to source information to close this gap.
11.3.1	Source and comprehend technical literature and credible information.

Course Outcomes : Learner will be able to

1. Apply fundamentals, identify sizing needs, model aircraft parameters, and develop preliminary designs while selecting optimal configurations. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5, LO 1.6)*
2. Apply aerodynamic principles to model lift and stability, identify configuration requirements, and develop optimized wing and tail designs for aircraft performance. *(LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 2.6)*
3. Identify configuration requirements, model aircraft geometry, refine layout designs, and evaluate configuration alternatives while collaborating effectively in teams. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5)*
4. Apply engineering principles to model and design propeller–engine and landing-gear systems, identify constraints, and select optimal configurations for performance and safety. *(LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 4.6)*
5. Analyze buckling and failure behavior of thin-walled structures by identifying key parameters and formulating structural stability models for accurate strength prediction. *(LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 5.5, LO 5.6)*

6. Analyze shear-carrying structures, model beam behavior, refine designs, evaluate web configurations, and collaborate to present optimized solutions. *(LO 6.1, LO 6.2, LO 6.3, LO 6.4, LO 6.5)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCAN703.1	3	3	3	--	--	--	--	--	--	--	--
HMCAN703.2	3	3	3	--	--	--	--	--	--	--	--
HMCAN703.3	--	3	3	--	--	--	--	3	3	--	3
HMCAN703.4	3	3	3	--	--	--	--	--	--	--	--
HMCAN703.5	3	3	--	3	--	--	--	--	--	--	--
HMCAN703.6	--	3	3	--	--	--	--	3	3	--	3
Average	**3**	**3**	**3**	**3**	**--**	**--**	**--**	**3**	**3**	**--**	**3**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. D. P. Raymer, *Aircraft Design: A Conceptual Approach*, 6th ed. Reston, VA: AIAA, 2018.
2. T. H. G. Megson, *Aircraft Structures for Engineering Students*, 5th ed. Oxford, UK: Butterworth-Heinemann, 2016.
3. J. D. Anderson Jr., *Aircraft Performance & Design*, 2nd ed. New York, NY: McGraw-Hill, 1999.
4. S. Farokhi, *Aircraft Propulsion*, 3rd ed. Hoboken, NJ: Wiley, 2014.
5. N. S. Currey, *Aircraft Landing Gear Design: Principles and Practices*, Reston, VA: AIAA, 2011.

Reference Books :

1. J. P. Fielding, *Introduction to Aircraft Design*, London, UK: Arnold, 2005.
2. I. H. Abbott and A. E. von Doenhoff, *Theory of Wing Sections*, New York, NY: Dover, 1959.
3. J. D. Anderson Jr., *Fundamentals of Aerodynamics*, 6th ed. New York, NY: McGraw-Hill, 2017.
4. L. R. Jenkinson and J. F. Marchman, *Aircraft Design Projects: For Engineering Students*, Oxford, UK: Butterworth-Heinemann, 2003.
5. S. P. Timoshenko and S. Woinowsky-Krieger, *Theory of Plates and Shells*, 2nd ed. New York, NY: McGraw-Hill, 1959.
6. D. J. Peery, *Aircraft Structures*, 2nd ed. New York, NY: McGraw-Hill, 1988.

Other Resources :

1. NPTEL, "Aircraft Design," Prof. A.K. Ghosh. https://onlinecourses.nptel.ac.in/noc21_ae04/preview
2. NPTEL, "Aircraft Design," Prof. A.K. Ghosh. https://onlinecourses.nptel.ac.in/noc21_ae04/preview
3. NPTEL, "Aircraft Design," Prof. A.K. Ghosh. https://onlinecourses.nptel.ac.in/noc21_ae04/preview
4. NPTEL, "Aircraft Design," Prof. A.K. Ghosh. https://onlinecourses.nptel.ac.in/noc21_ae04/preview
5. NPTEL, "Aircraft Design," Prof. A.K. Ghosh. https://onlinecourses.nptel.ac.in/noc21_ae04/preview

IN-SEMESTER ASSESSMENT (50 MARKS)

1. **Continuous Assessment (20 Marks)**

   Suggested breakup of distribution

Class tests	:	05 Marks
Task based group activity	:	05 Marks
Course Project	:	05 Marks
Regularity and Active Participation	:	05 Marks

2. **Mid Semester Exam (30 Marks)**
   Mid semester examination will be based on 40% to 50% of the syllabus

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20-30% weightage, and the syllabus covered from MSE to ESE carrying 70-80% weightage.

Course Type	Course Code	Course Name	Credits
HML	HMLAN701	AERO MODELING AND SIMULATION LABORATORY	02

Examination Scheme		
Continuous Assessment	**End Semester Exam (ESE)**	**Total**
50	--	50

Pre-requisite :

1. HMCAN501 - Basics of Aeronautical Engineering
2. MEPEC5011 - Finite Element Analysis
3. MEPEC5012 - Computer Aided Engineering
4. HMCAN602 - Low Speed Aerodynamics and Flight Dynamics
5. HMCAN804 - Aircraft Control Systems

Program Outcomes addressed :

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO4: Conduct Investigations of Complex Problems
4. PO5: Engineering Tool Usage
5. PO8: Individual and Collaborative Team work
6. PO9: Communication

Course Objectives:

1. Develop practical skills in physical aero-modelling by interpreting airfoil geometry, selecting materials, fabricating components, performing CG balancing, and demonstrating safe and efficient workshop practices.
2. Build competency in RC aircraft system integration through structural reinforcement, propulsion and control system configuration, execution of pre-flight checks, and assessment of in-flight performance.
3. Strengthen simulation proficiency in CFD by creating and meshing airfoil geometries, applying turbulence models, performing aerodynamic simulations, and analyzing/optimizing performance using computational tools.
4. Develop applied skills in Fluid–Structure Interaction (FSI) analysis through geometry/mesh setup, execution of steady and unsteady coupled simulations, evaluation of transient structural responses, and validation of results using engineering post-processing techniques.

Module	Detailed Contents	Hrs.
	Course Introduction The Aero Modeling and Simulation Laboratory offers a hands-on learning experience that combines physical aircraft model construction with modern simulation techniques. Students build and test scaled aircraft prototypes to	**01**

	understand aerodynamic behavior, stability, and control. They also use CAD, CFD, and dynamic simulation tools to analyze airflow, evaluate performance, and model aircraft responses to different conditions. This laboratory enables students to apply theoretical concepts, develop practical design skills, and gain exposure to industry-relevant tools. By the end of the course, learners will be capable of designing, analyzing, and testing basic aircraft systems through both physical and virtual methods.	
01.	**Basics of Aero Model Construction (Physical Modeling)** ***Learning Objective/s:***	**17**
	To construct fundamental aircraft models by applying basic geometric understanding, material selection, and fabrication techniques.	
	Introduction to model aircraft types Reading airfoil profiles and geometry scaling Material selection: balsa wood, foam, carbon rods, adhesives Cutting, shaping, sanding, and assembly processes Fabrication of simple gliders and free-flight models Center of gravity (CG) estimation and balancing techniques Safety protocols and best practices in the workshop	
	Task 1 Apply airfoil interpretation techniques to read and scale a selected airfoil profile to model dimensions, and analyse the weight–strength characteristics of balsa, foam, and carbon rods to select the most suitable materials for wing and fuselage construction. *LO 1.1 Interpret and scale airfoil geometries and analyze material properties to justify the selection of suitable construction materials for model aircraft structures. (PI 1.3.1, PI 1.2.1, PI 2.2.2, PI 2.4.4, PI 5.1.1)* **Task 2** Apply appropriate manufacturing processes to cut, shape, and prepare wing and fuselage parts, and create structurally accurate components by assembling them according to fabrication guidelines and safety protocols. *LO 1.2 Apply fabrication techniques to construct accurate wing and fuselage components and assemble a functional glider model in adherence to workshop safety practices. (PI 4.1.3, PI 4.1.2, PI 5.2.2, PI 8.1.2, PI 8.1.1)* **Task 3** Analyse the mass distribution of the model to estimate the center of gravity, evaluate its balance using a CG stand, and assess the aircraft's stability through a controlled glide test. *LO 1.3 Analyze mass distribution to determine the center of gravity and evaluate the stability of the model through systematic balance and glide testing. (PI 2.4.1, PI 4.3.2, PI 4.3.4, PI 8.2.1, PI 5.2.1)*	

	Self-Learning Topics: *Influence of Airfoil Shape and CG Position on the Flight Performance of Simple Model Aircraft.*	
02.	**Advanced Aero Model Fabrication & Flight Testing (Physical Modeling)**	**18**
	Learning Objective/s: *To integrate structural, control, and propulsion components to build RC aircraft and evaluate their performance through flight testing.*	
	RC aircraft structural design and reinforcement Wing loading and structural stability considerations Installation of propulsion systems and power units Servo mounting, control linkages & radio configuration Pre-flight testing: range test, control surface verification Flight trials: take-off, trimming, stability checks Data recording: flight duration, climb performance, glide ratio Troubleshooting typical flight issues (stall, roll instability, CG imbalance)	
	Task 4 Apply suitable structural reinforcement methods for the fuselage and wings, determine wing loading through measured mass and wing area, and evaluate its impact on the aircraft's structural stability and expected flight performance. *LO 2.1 Apply structural design methods to reinforce RC aircraft components and analyze calculated wing loading to determine its effect on structural stability and flight performance. (PI 1.3.1, PI 1.2.1, PI 2.4.1, PI 4.1.3, PI 5.1.1)* **Task 5** Assemble the motor, ESC, battery, servos, and linkages, configure the radio system to achieve accurate control surface deflections, and evaluate system responsiveness to verify operational readiness. *LO 2.2 Integrate propulsion and control components and configure the radio system to verify correct control responses and functional readiness. (PI 1.4.1, PI 4.1.2. PI 5.2.2, PI 5.3.1, PI 8.1.2)* **Task 6** Perform pre-flight checks, carry out controlled flight trials, and assess aircraft performance to identify and diagnose issues such as instability, stalling tendencies, or CG imbalance. *LO 2.3 Analyse pre-flight checks and flight behaviour to assess aircraft performance and diagnose instability, stalling, or CG-related issues. (PI 1.1.1, PI 2.4.4, PI 4.3.2, PI 4.3.4, PI 8.2.1)*	
	Self-Learning Topics:	
	Analysis of Factors Affecting Flight Performance and Stability in RC Aircraft.	

<table>
<tr><td rowspan="5">03.</td><td>Aerodynamic Analysis Using CFD (Simulation)</td><td rowspan="5">12</td></tr>
<tr><td>Learning Objective/s:
To set up and analyze aerodynamic simulations to determine lift, drag, and flow characteristics around aircraft components.</td></tr>
<tr><td>Introduction to CFD workflow: geometry → meshing → boundary conditions → solution
2D airfoil analysis (NACA profiles)
Mesh generation: structured vs unstructured grids
Selection of turbulence models (k-ε, k-ω SST)
Simulation of flow over wings at varying angles of attack
Post-processing: Cp, Cl, Cd, streamlines, velocity vectors
Comparison of CFD results with analytical data
Aerodynamic optimization techniques (basic)</td></tr>
<tr><td>Task 7
Construct the 2D NACA airfoil geometry, generate structured and unstructured meshes, and configure boundary conditions and solver parameters to establish a complete CFD model setup.
LO 3.1 Develop a complete CFD pre-processing workflow by generating 2D NACA airfoil geometry, creating structured and unstructured meshes, and configuring boundary conditions and solver parameters. (PI 1.3.1, PI 2.3.1, PI 2.2.4, PI 4.1.2, PI 4.1.3, PI 5.1.1, PI 5.3.1, PI 9.1.2)
Task 8
Execute airflow simulations using appropriate turbulence models, analyse the resulting aerodynamic parameters (C_l, C_d, C_p, flow fields), and propose parameter modifications to enhance aerodynamic performance.
LO 3.2 Perform CFD simulations using suitable turbulence models and analyze aerodynamic parameters such as C_l, C_d, and C_p to evaluate their influence on airfoil performance. (PI 1.3.1, PI 1.2.1, PI 2.4.1, PI 2.4.4, PI 4.3.2, PI 5.2.2, PI 9.3.1)</td></tr>
<tr><td>Self-Learning Topics:
Effect of Turbulence Models and Mesh Strategies on the Accuracy of Airfoil CFD Predictions.</td></tr>
<tr><td rowspan="3">04.</td><td>Fluid–Structure Interaction (FSI) Simulation</td><td rowspan="3">12</td></tr>
<tr><td>Learning Objective/s:
To model coupled fluid–structure interaction problems by setting up fluid and structural domains with appropriate boundary conditions.
To simulate and analyze deformation, stress response, and dynamic behaviour of structures under flow-induced loads using CFD–FEA coupling tools.</td></tr>
<tr><td>Introduction to fluid–structure interaction fundamentals</td></tr>
</table>

	Governing equations: Navier–Stokes equations and structural dynamics (FEA formulation) Geometry creation and domain setup for FSI Mesh generation for fluid and solid domains Boundary conditions for one-way and two-way coupling Solving steady and unsteady FSI problems (flutter, vortex-induced vibration, panel deformation) Transient response analysis: displacement, stress, damping, natural frequencies Validation and parameter sensitivity using different flow velocities and material properties Post-processing: deformation contours, pressure fields, von Mises stress, mode shapes Introduction to coupled CFD–FEA simulation environments	
	Task 9 Develop the fluid and structural geometries, generate suitable fluid–solid meshes, apply FSI boundary conditions, and execute steady or unsteady coupled simulations for cases such as flutter or panel deformation. *LO 4.1 Develop an FSI model by creating fluid and structural geometries, generating compatible meshes, applying appropriate coupling boundary conditions, and execute steady or unsteady coupled simulations for flutter or deformation analysis. (PI 1.3.1, PI 2.3.1, PI 2.2.4, PI 4.1.2, PI 4.1.3, PI 5.1.1, PI 5.3.1, PI 9.1.2)* **Task 10** Perform transient FSI simulations to obtain structural responses such as displacement, stress, and vibration characteristics, analyze deformation and pressure fields through post-processing, and evaluate the results by comparing them with reference or analytical data. *LO 4.2 Perform transient FSI simulations to generate structural response data, analyze deformation and pressure fields through post-processing, and evaluate the results by comparing them with reference or analytical data. (PI 1.4.1, PI 2.4.1, PI 2.4.4, PI 4.3.2, PI 4.3.4, PI 5.2.2, PI 9.3.1)*	
	Self-Learning Topics: *Understanding Coupled Fluid–Structure Interaction Mechanisms and Their Role in Predicting Structural Deformation Under Aerodynamic Loads.*	
	Total	**60**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.2.1	Apply laws of natural science to an engineering problem.
1.3.1	Apply fundamental engineering concepts to solve engineering problems.

1.4.1	Apply mechanical engineering concepts to solve engineering problems.
2.2.2	Identify, assemble and evaluate information and resources.
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate models of a system or process.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.
4.1.2	Examine relevant methods, tools and techniques of experiment design, system calibration, data acquisition, analysis and presentation.
4.1.3	Apply appropriate instrumentation and/or software tools to make measurements of physical quantities.
4.3.2	Analyze data for trends and correlations, stating possible errors and limitations.
4.3.4	Synthesize information and knowledge from raw data to reach appropriate conclusions.
5.1.1	Identify modern engineering tools for drafting, modeling and analysis.
5.2.1	Identify strengths and limitations of tools for acquiring information, modeling, simulating, monitoring performance, and creating designs.
5.2.2	Demonstrate proficiency in using discipline-specific tools.
5.3.1	Discuss limitations and validate tools, techniques, and resources.
8.1.1	Recognize a variety of working and learning preferences and appreciate team diversity.
8.1.2	Implement norms of practice for effective teamwork to accomplish a goal.
8.2.1	Demonstrate effective communication, problem-solving, conflict resolution and leadership skills.
9.1.2	Produce clear, well-constructed, and well-supported written engineering documents.
9.3.1	Create engineering-standard figures, reports and drawings to complement documentation.

Course Outcomes: A learner will be able to

1. To apply airfoil interpretation and fabrication techniques to build a model aircraft, and analyze its mass distribution and flight behaviour for proper CG placement and stable performance. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4)*
2. To apply structural design, propulsion–control integration, and pre-flight evaluation methods to assess RC aircraft performance and identify factors affecting stability and flight behaviour. *(LO 2.1, LO 2.2, LO 2.3, LO 2.4)*
3. To apply CFD pre-processing methods to create airfoil models and meshes, and analyze simulation results using suitable turbulence models to evaluate aerodynamic performance. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4)*
4. To apply FSI modelling techniques to set up coupled fluid–structure simulations and analyze transient structural responses to evaluate deformation, pressure effects, and overall system behaviour. *(LO 4.1, LO 4.2, LO 4.3, LO 4.4)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMLAN701.1	3	3	--	3	3	--	--	3	--	--	--
HMLAN701.2	3	3	--	3	3	--	--	3	--	--	--
HMLAN701.3	3	3	--	3	3	--	--	--	3	--	--
HMLAN701.4	3	3	--	3	3	--	--	--	3	--	--
Average	**3**	**3**	**--**	**3**	**3**	**--**	**--**	**3**	**3**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. P. Ozdemir, RC Model Aircraft Design & Construction. New York, NY, USA: McGraw-Hill, 2014.
2. A. S. Hall, Model Aircraft Aerodynamics: A Practical Guide for Builders and Flyers, 5th ed. Ramsgate, U.K.: Traplet Publications, 2015.
3. K. D. Stewart, RC Airplane Handbook: Building, Testing, and Flying Techniques. Irvine, CA, USA: Horizon Hobby Press, 2012.
4. D. B. Scott, The Encyclopedia of Radio-Controlled Aircraft Modelling Techniques. London, U.K.: Nexus Special Interests, 2009.
5. M. J. Selig, Practical Airfoil Aerodynamics for Model Aircraft. Champaign, IL, USA: SoarTech Publications, 2010.
6. R. R. Boucher, Electric Motor Handbook for Model Aircraft and Drones, 2nd ed. Toronto, ON, Canada: Model Aeronautics Press, 2016.
7. Model Aeronautics Association of America (MAAA), Model Aircraft Safety and Operations Handbook. Washington, DC, USA: MAAA, 2018.
8. Academy of Model Aeronautics (AMA), AMA Handbook of Safety Codes and Flight Testing Standards. Muncie, IN, USA: AMA Publications, 2020.
9. T. J. McCormick, Practical Guide to Building Balsa and Foam Aircraft. London, U.K.: Argus Books, 2007.
10. F. Zaic, Model Aircraft Yearbook: Construction, Aerodynamics, Testing. New York, NY, USA: Model Builder Press, 2005.

Reference Books :

1. J. H. McMasters and M. P. Henderson, Low-Speed Wind Tunnel Testing, 3rd ed. New York, NY, USA: Wiley-Interscience, 1990.
2. F. M. White, Fluid Mechanics, 8th ed. New York, NY, USA: McGraw-Hill, 2016.
3. J. D. Anderson, Fundamentals of Aerodynamics, 6th ed. New York, NY, USA: McGraw-Hill, 2017.
4. B. L. Stevens and F. L. Lewis, Aircraft Control and Simulation, 3rd ed. Hoboken, NJ, USA: Wiley, 2015.
5. A. Sadraey, Aircraft Design: A Systems Engineering Approach, Boca Raton, FL, USA: CRC Press, 2012.
6. R. H. Barnard and D. R. Philpott, Aircraft Flight: A Description of the Physical Principles, 3rd ed. Harlow, UK: Pearson Education, 2010.
7. O. C. Zienkiewicz, R. L. Taylor, and J. Z. Zhu, The Finite Element Method: Its Basis and Fundamentals, 7th ed. Oxford, UK: Butterworth-Heinemann, 2013.
8. T. J. Chung, Computational Fluid Dynamics, 2nd ed. Cambridge, UK: Cambridge Univ. Press, 2010.

Other Resources :

1. **NPTEL – Introduction to Aircraft Stability & Control (IIT Kanpur), Prof. A. Mani**
Link: https://nptel.ac.in/courses/101104014
2. **NPTEL – Introduction to Aerodynamics (IIT Kharagpur), Prof. A. Ghosh**
Link: https://nptel.ac.in/courses/101105050
3. **NPTEL – Basic CFD for Engineers (IIT Kanpur), Prof. T. Sundararajan**
Link: https://nptel.ac.in/courses/112104118
4. **ANSYS Learning Hub – Introduction to ANSYS Fluent (CFD)**
Link: https://www.ansys.com/training-center
5. **ANSYS Learning Hub – Introduction to ANSYS DesignModeler (Geometry & Meshing)**
Link: https://www.ansys.com/training-center
6. **edX – Aerodynamics and Aircraft Performance (TU Delft)**
Link: https://www.edx.org/course/aerodynamics
7. **Udemy – RC Aircraft Build & Flight Training (Model Aircraft Workshop)**
Link: https://www.udemy.com/topic/rc-airplane/
8. **Udemy – ANSYS Fluent for Beginners (Hands-on CFD)**
Link: https://www.udemy.com/course/ansys-fluent-beginners/
9. **MIT OpenCourseWare – Unified Engineering: Aerodynamics Module**
Link: https://ocw.mit.edu/courses/aeronautics-and-astronautics/
10. **NASA Beginner's Guide to Aeronautics (Practical Airfoil & Airplane Basics)**
Link: https://www.grc.nasa.gov/www/k-12/airplane/bga.html

IN-SEMESTER ASSESSMENT (50 MARKS)

Continuous Assessment (50 Marks)

Performance based on completion of task : 20 Marks
Oral conducted during the practical performance : 05 Marks

Course Project (max 4 students) to demonstrate concept : 20 Marks
Students will complete one mini-project from the following categories:

- Design and fabrication of an RC aircraft or glider with flight testing
- Aerodynamic analysis of an airfoil/wing using CFD
- Fluid–structure interaction (FSI) simulation of a deformable aero-component

Regularity and Active Participation : 05 Marks

Course Type	Course Code	Course Name	Credits
HMC	HMCAN804	AIRCRAFT CONTROL SYSTEMS	04

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. ESC101 - Engineering Mechanics
2. HMCAN501 - Basics of Aeronautical Engineering
3. HMCAN602 - Low Speed Aerodynamics and Flight Dynamics

Program Outcomes addressed :

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO4: Conduct Investigations of Complex Problems
4. PO6: Engineer & Society / Sustainability
5. PO8: Individual & Team Work
6. PO9: Communication
7. PO10: Project Management & Finance
8. PO11: Life-Long Learning

Course Objectives :

1. Explore the fundamentals of aircraft control systems, including control-surface functions and stability requirements essential for safe and responsive flight.
2. Analyze aircraft dynamic behavior by applying equations of motion, evaluating trim conditions, interpreting stability derivatives, and differentiating major flight modes.
3. Construct simplified control models using transfer functions and PID concepts, and assess stability through introductory root-locus or frequency-response reasoning.
4. Formulate state-space models, evaluate system controllability and observability, and apply optimal control and estimation concepts such as LQR and Kalman filtering.
5. Investigate the roles of sensors, actuators, and flight-control computers, and synthesize their integration within aircraft and UAV fly-by-wire architectures.
6. Identify and evaluate key flight control components, including sensors, actuators, flight computers, fly-by-wire systems, and redundancy architecture.

Module	Details	Hrs
	Course Introduction This course provides a focused foundation in aircraft stability and control, emphasizing how an aircraft responds to pilot commands, control-surface inputs, and aerodynamic disturbances. Students learn the roles of primary and secondary flight controls, key stability concepts, and the behavior of aircraft in major flight modes. The course integrates classical control ideas—such as transfer functions, PID-based autopilot loops, and basic stability assessment—with introductory modern methods including state-space representation, controllability, observability, LQR concepts, and Kalman filter applications. It also covers essential control-system components like sensors, actuators, flight control computers, fly-by-wire frameworks, and redundancy practices. By the end of the course, learners will understand how aircraft motion and control laws interact within real operational systems, including emerging autonomous platforms.	**01**
01.	**Introduction to Aircraft Control** ***Learning Objective/s:*** 1. *To differentiate between open-loop and closed-loop aircraft control systems and identify the role of primary and secondary flight control surfaces.* 2. *To interpret basic aircraft stability concepts and classify major flight modes in longitudinal and lateral-directional motion.*	**8-10**
	Contents: Purpose of aircraft control systems, Open-loop vs closed-loop control, Primary & secondary flight controls, Basic stability concepts (static vs dynamic), Flight modes (longitudinal & lateral-directional)	
	Self-Learning Topics: *Historical evolution of aircraft control systems and early autopilot designs (Wright brothers to modern fly-by-wire).*	
	Learning Outcomes : *A learner will be able to* *LO 1.1 Apply fundamental laws of engineering to identify the role of aircraft control systems in achieving maneuverability and stability. (PI 1.3.1)* *LO 1.2 Apply fundamental mathematical relationships to compare the dynamic behavior of open-loop and closed-loop control systems. (PI 1.1.1)* *LO 1.3 Identify the functional roles, operating axes, and key parameters that distinguish primary from secondary flight control systems. (PI 2.1.2)* *LO 1.4 Formulate relations to establish control-surface effects on pitch, roll and yaw stability. (PI 2.3.1)* *LO 1.5 Analyze aircraft response data to distinguish between static and dynamic stability characteristics. (PI 4.1.2)* *LO 1.6 Examine and interpret longitudinal and lateral-directional flight mode behavior to assess aircraft performance and stability. (PI 4.2.1)*	

02.	**Aircraft Dynamics** ***Learning Objective/s:*** 1. *To Interpret aircraft equations of motion, trim conditions, and stability derivatives in the context of longitudinal and lateral dynamics.* 2. *To identify and classify common aircraft stability modes, including phugoid, short-period, roll, and yaw motions.* **Contents:** Equations of motion (conceptual understanding), Longitudinal and lateral dynamics, Trim conditions and linearization (basic idea), Stability derivatives — meaning and role Common stability modes (phugoid, short-period, roll, yaw) ***Self-Learning Topics:*** *Study real aircraft phugoid and short-period response examples using flight test data or simulation videos.* ***Learning Outcomes :*** *A learner will be able to* *LO 2.1 Apply mathematical principles to represent and analyze aircraft equations of motion for predicting vehicle behavior. (PI 1.1.1)* *LO 2.2 Apply fundamental engineering principles to classify aircraft responses into longitudinal and lateral–directional dynamic modes. (PI 1.3.1)* *LO 2.3 Identify and justify the mathematical and physical assumptions required to model longitudinal and lateral–directional aircraft dynamics with appropriate accuracy. (PI 2.3.2)* *LO 2.4 Identify the role of key stability derivatives and define how they influence the aircraft's dynamic response. (PI 2.1.3)* *LO 2.5 Distinguish major aircraft stability modes by identifying their motion characteristics and relevance to performance requirements. (PI 4.1.1)* *LO 2.6 Analyze the influence of change in configuration or parameter on aircraft stability modes to support informed design decisions. (PI 4.1.2)*	**9-11**
03.	**Classical Control Methods** ***Learning Objective/s:*** 1. *Apply basic transfer-function concepts and PID control principles to typical aircraft attitude, altitude, and heading control loops.* 2. *Interpret fundamental stability analysis ideas (root-locus and Bode concepts) in the context of aircraft autopilot behavior.* **Contents:** Transfer functions (intro only), PID controllers in aircraft control, Stability analysis basics (root locus/Bode concept only), Basic autopilot loops: attitude, altitude, and heading hold. ***Self-Learning Topics:*** *Real-world PID tuning examples for aircraft attitude or altitude hold using open-source flight controller platforms (e.g., PX4 / ArduPilot demonstration videos).*	**9-11**

	Learning Outcomes : *A learner will be able to* *LO 3.1 Formulate simplified models of aircraft control behavior using basic transfer-function representations. (PI 2.3.1)* *LO 3.2 Apply PID control actions to adjust and improve aircraft response characteristics in simple control loop models. (PI 2.4.1)* *LO 3.3 Examine aircraft control system stability using introductory root-locus or Bode-plot reasoning. (PI 4.1.2)* *LO 3.4 Define the objectives and performance roles of attitude-, altitude-, and heading-hold autopilot loops to establish their significance in overall control-system behavior. (PI 4.1.1)* *LO 3.5 A Task-Based Group Activity Before MSE (Part I) (PI 6.3.2, PI 6.4.2, PI 8.1.2, PI 8.2.1, PI 9.1.2, PI 9.2.2, PI 10.3.1, PI 10.3.2, PI 11.1.2, PI 11.3.1)* ***Aircraft Stability & Control System Modeling and Analysis Task*** *A group of maximum 4 students will work collaboratively* ***i. Control System Identification:*** *Identify the purpose of aircraft control systems; distinguish between open-loop and closed-loop behavior; classify primary and secondary flight controls based on their functional roles.* ***ii. Stability Analysis:*** *Differentiate static and dynamic stability using response characteristics; examine longitudinal and lateral–directional motions; describe major stability modes such as phugoid, short-period, roll, and yaw oscillations.* ***iii. Dynamics Interpretation:*** *Interpret the conceptual equations of motion for aircraft; identify trim and linearization requirements; relate key stability derivatives to aircraft dynamic responses.* ***iv. Control Modeling:*** *Develop simplified transfer-function models of basic aircraft control channels; state the assumptions used; demonstrate qualitatively how PID actions modify system response.* ***v. Autopilot & Stability Evaluation:*** *Use introductory root-locus or Bode-based reasoning to evaluate stability; examine attitude-, altitude-, and heading-hold autopilot loops and assess their influence on control-system behavior.* *Teams will submit a short report containing diagrams, simplified models, stability sketches, control-loop representations, and clear justification for all analytical conclusions.*	
04.	**Modern Control Basics** ***Learning Objective/s:*** 1. *Outline state-space representation, controllability, and observability concepts for aircraft control systems.* 2. *Discuss the purpose of LQR and Kalman filtering in modern flight control without detailed mathematical derivation.*	**8-10**
	Contents: State-space representation (conceptual), Controllability and observability (simple explanation), LQR concept (no advanced math), Introduction to Kalman filter (why used, not derivation)	
	Self-Learning Topics:	
	Modern autopilot systems transition from PID to state-space control architectures in commercial and military aircraft.	
	Learning Outcomes :	
	A learner will be able to *LO 4.1 Apply fundamental engineering principles to represent simple dynamic systems in state-space form by defining appropriate states, inputs, and outputs. (PI 1.3.1)*	

	LO 4.2 Apply basic linear algebra concepts to determine the controllability or observability of a simplified dynamic system. (PI 1.1.1) *LO 4.3 Formulate a conceptual control model and evaluate how different LQR weighting choices shape the system's response and stability. (PI 2.3.1)* *LO 4.4 Identify the objective of state estimation and explain why a Kalman filter is required to address noise and uncertainty in a control system. (PI 2.1.3)* *LO 4.5 Define the performance objectives and scope of a control system represented in state-space form to support further analysis and design decisions. (PI 4.1.1)* *LO 4.6 Examine system behavior and use appropriate analytical techniques to select suitable conceptual control methods such as LQR or state-feedback. PI 4.1.2)*	
05.	**Flight Control System Components**	**8-10**
	Learning Objective/s: 1. *Identify and classify major aircraft control system components, including sensors, actuators, and flight control computers.* 2. *Evaluate the role of fly-by-wire architecture and redundancy principles in ensuring safe aircraft control operation.*	
	Contents: Sensors: IMU, gyroscope, accelerometer, air data sensors, Actuators: servos, motors, control surface linkages, Flight control computers — basic architecture, Fly-by-wire overview, Safety & redundancy basics.	
	Self-Learning Topics: *Working of IMUs, GPS, and redundant sensors in modern aircraft flight control systems.*	
	Learning Outcomes : *A learner will be able to* *LO 5.1 Apply fundamental sensing and measurement principles of IMUs, gyroscopes, accelerometers, and air-data sensors to determine the key quantities required for flight control. (PI 1.3.1)* *LO 5.2 Apply basic mathematical relationships to evaluate actuator behavior using performance parameters such as response rate and deflection limits. (PI 1.1.1)* *LO 5.3 Integrate sensing, control-law, and actuation principles to formulate a simplified model of flight-control computer architecture. (PI 2.3.1)* *LO 5.4 Identify the objectives of fly-by-wire systems and explain how electronic signalling and control laws are used to achieve improved stability and aircraft response. (PI 2.1.3)* *LO 5.5 Examine sensor and actuator integration within a flight-control loop to evaluate how they contribute to achieving the required system behavior. (PI 4.1.1)* *LO 5.6 Evaluate sensor availability and actuator capabilities to select an appropriate control-system configuration that meets flight-control performance requirements. (PI 4.1.2)*	
06.	**Drone Control Systems and Architecture**	**10-12**
	Learning Objective/s: 1. *To identify and analyze the key control-system components that enable stable and autonomous drone (UAV) operation.*	

2. *To interpret multirotor drone dynamics, control-loop structure, actuator mixing, and redundancy considerations in UAV flight controllers.*

Contents:

Drone dynamics overview: multirotor configuration, thrust vectoring, motor mixing, attitude–rate relationship.
Drone sensors: IMU, gyroscope, accelerometer, magnetometer, barometer, GPS, optical flow.
Drone actuators: brushless DC motors, ESCs, propeller–motor dynamics, mixer logic for quad/hexa/octo.
Flight control computers: architecture (PX4, ArduPilot), inner-loop (rate) and outer-loop (attitude/position) structure.
Communication & signal pathways: RC link, telemetry link, fail-safe triggers.
Fly-by-wire in drones: electronic stabilization, PID-based attitude hold, sensor fusion.
Safety & redundancy principles: sensor redundancy, failsafe logic, return-to-home (RTH), geofencing, motor-loss handling, battery health management.

Self-Learning Topics:

Working of PX4/ArduPilot flight stack (e.g., IMU fusion using EKF, mixer algorithms, mode switching).

Real flight logs: interpreting IMU data, motor output, PID loops, and GPS tracks from open-source drone datasets.

Learning Outcomes :

A learner will be able to

LO 6.1 Apply fundamental sensing and engineering principles to use IMU, gyro, accelerometer, magnetometer, barometer, and GPS data for determining key state variables in drone flight control. (PI 1.3.1)

LO 6.2 Apply basic mathematical relationships to evaluate motor–propeller response characteristics and quantify actuator-mixing effects for quadrotor stabilization. (PI 1.1.1)

LO 6.3 Integrate sensing, control, and actuation principles to formulate a simplified model of a UAV flight controller incorporating sensor fusion, control laws, mixer logic, and actuator outputs. (PI 2.3.1)

LO 6.4 Identify the objectives of electronic stabilization and sensor-fusion algorithms and explain how they enable attitude hold, position hold, and autonomous flight in drones. (PI 2.1.3)

LO 6.5 Define the functional requirements for integrating sensors, ESCs, motors, and control laws within the inner- and outer-loop structures of a drone autopilot. (PI 4.1.1)

LO 6.6 Examine redundancy and fail-safe options such as return-to-home, geofencing, battery failsafe, and sensor fallback to evaluate their effectiveness in improving drone operational safety. (PI 4.1.2)

LO 6.7 A Task-Based Group Activity After MSE (Part II) (PI 6.3.2, PI 6.4.2, PI 8.1.2, PI 8.2.1, PI 9.1.2, PI 9.2.2, PI 10.3.1, PI 10.3.2, PI 11.1.2, PI 11.3.1)

Conceptual Design and Evaluation of a Drone Flight-Control & Safety Architecture

A group of maximum 4 students will work collaboratively to design a conceptual flight-control subsystem for a multirotor drone, incorporating sensor fusion, stabilization logic, actuator behavior, motor mixing, and system redundancy.

	The task requires producing a unified, system-level representation of how a drone senses, decides, stabilizes, and responds to failures. *Important aspects to be addressed* *i.* ***Develop a unified flight-control system architecture*** *showing:* *Sensor fusion (IMU, magnetometer, barometer, GPS).* *Inner-loop rate control and outer-loop attitude/altitude control.* *Motor-mixer block for multirotor actuation.* *Flight-control computer signal flow.* *ii.* ***Prepare a sensor–state mapping table identifying which sensors estimate:*** *Attitude, angular rates, altitude, heading, velocity, and position.* *iii.* ***Analyze actuator behavior by:*** *Describing ESC–motor dynamics.* *Creating a conceptual quadrotor motor-mixing table for roll, pitch, yaw, and throttle commands.* *iv.* ***Propose stabilization logic (conceptual PID/rate control) for:*** *Attitude hold and/or altitude hold.* *Justify how sensor feedback drives stabilization.* *v.* ***Evaluate redundancy and fail-safe strategies, including:*** *Sensor redundancy (IMU fallback, magnetometer/gps switching).* *GPS-loss mode transitions.* *Battery/voltage failsafe actions.* *Motor-loss behavior and safe landing/RTH options.* *vi.* ***Document project management activities, including:*** *Team roles and responsibilities.* *Task breakdown and timeline (Gantt chart).* *vii.* ***Prepare a professional report and presentation summarizing:*** *The system architecture* *Control logic* *Safety mechanisms* *Design rationale* *Group reflections and learning sources* *Teams will submit a short report containing diagrams, simplified models, stability sketches, control-loop representations, and clear justification for all analytical conclusions.*	
	Course Conclusion	**01**
	Total	**60**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems.
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem.
2.3.1	Combine scientific principles and engineering concepts to formulate models appropriate for accuracy and applicability.

2.3.2	Identify mathematical and physical assumptions needed for modeling.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
4.1.1	Define a problem, its scope, and importance for investigation.
4.1.2	Examine methods, tools, and techniques for calibration, measurement, analysis, and presentation.
4.2.1	Design and develop an experimental approach with appropriate equipment and procedures.
6.3.2	Understand relationships among technical, socio-economic, and environmental dimensions of sustainability.
6.4.2	Apply preventive engineering and sustainable development principles to engineering activities.
8.1.2	Implement teamwork norms (roles, rules, agendas) to accomplish a goal.
8.2.1	Demonstrate effective communication, problem-solving, conflict resolution, and leadership skills.
9.1.2	Produce clear, well-supported written engineering documents.
9.2.2	Deliver effective oral presentations to technical and non-technical audiences.
10.3.1	Identify tasks and resources required for an engineering activity.
10.3.2	Use project management tools to schedule and complete a project on time and within budget.
11.1.2	Identify knowledge gaps and source information to close them.
11.3.1	Source and comprehend technical and credible literature.

Course Outcomes: Learner will be able to

1. Analyze aircraft control systems and stability characteristics to evaluate manoeuvrability and flight-mode behavior. *(LO1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5, LO 1.6)*
2. Analyze aircraft dynamic behavior and stability modes using equations of motion, trim concepts, and stability derivatives to support performance and design decisions. *(LO: 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 2.6)*
3. Apply classical control methods and autopilot concepts to model aircraft control behavior, assess stability, and evaluate closed-loop flight-control performance. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5)*
4. Apply state-space methods, estimation concepts, and optimal control strategies to analyze system behavior and support control-system design decisions.*(LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 4.6)*
5. Analyze sensor, actuator, and flight-control computer functions to support the selection and integration of effective aircraft control-system configurations.
(LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 5.5, LO 5.6)
6. Analyze drone control-system components, stabilization logic, and safety mechanisms to support effective autopilot integration and reliable UAV operation. *(LO 6.1, LO 6.2, LO 6.3, LO 6.4, LO 6.5, LO 6.6, LO 6.7)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCAN804.1	3	3	--	3	--	--	--	--	--	--	--
HMCAN804.2	3	3	--	3	--	--	--	--	--	--	--
HMCAN804.3	--	3	--	3	--	3	--	3	3	3	3
HMCAN804.4	3	3	--	3	--	--	--	--	--	--	--
HMCAN804.5	3	3		3	--	--	--	--	--	--	--
HMCAN804.6	3	3	--	3	--	3	--	3	3	3	3
Average	**3**	**3**	**--**	**3**	**--**	**3**	**--**	**3**	**3**	**3**	**3**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. B. L. Stevens and F. L. Lewis, Aircraft Control and Simulation: Dynamics, Controls Design, and Autonomous Systems, 4th ed. Hoboken, NJ: Wiley, 2020.
2. R. C. Nelson, Flight Stability and Automatic Control, 3rd ed. New York, NY: McGraw-Hill, 1998.
3. B. Etkin and L. D. Reid, Dynamics of Flight: Stability and Control, 3rd ed. New York, NY: Wiley, 1996.
4. R. Beard and T. McLain, Small Unmanned Aircraft: Theory and Practice, Princeton, NJ: Princeton University Press, 2012.
5. P. Corke, Robotics, Vision and Control: Fundamental Algorithms for UAV Control, 2nd ed. Cham: Springer, 2017.

Reference Books :

1. R. Stengel, Flight Dynamics, Princeton, NJ: Princeton University Press, 2004.
2. E. Lavretsky and K. A. Wise, Robust and Adaptive Control: With Aerospace Applications, London, UK: Springer, 2013.
3. H. K. Khalil, Nonlinear Systems, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 2002.
4. S. Thrun, W. Burgard, and D. Fox, Probabilistic Robotics, Cambridge, MA: MIT Press, 2005.
5. P. Castillo, R. Lozano, and A. Dzul, Modelling and Control of Mini-Flying Machines, London, UK: Springer, 2005.
6. T. Fossen, Guidance and Control of Ocean Vehicles & Unmanned Systems, Oxford, UK: Wiley, 2021.

Other Resources :

1. **NPTEL**, *"Flight Dynamics and Control,"* **Prof. A. K. Ghosh**, IIT Kanpur.
   Available: https://nptel.ac.in/courses/101104014/
2. **NPTEL**, *"Control Engineering,"* **Prof. S. D. Agashe**, IIT Bombay.
   Available: https://nptel.ac.in/courses/108101037/
3. **NPTEL**, *"Introduction to UAV Systems,"* **Prof. H. V. Sridhar**, IISc Bengaluru.
   Available: https://nptel.ac.in/courses/101104061/

4. **MIT OpenCourseWare**, *"Flight Vehicle Dynamics,"* MIT Department of Aeronautics & Astronautics.
   Available: https://ocw.mit.edu/courses/16-333-aircraft-vehicle-dynamics/
5. **PX4 Autopilot Documentation**, *Official Open-Source UAV Flight Control Stack*.
   Available: https://docs.px4.io/
6. **ArduPilot Dev Guide**, *Open-Source Autopilot for Multirotors, Fixed-Wing, and VTOL UAVs*.
   Available: https://ardupilot.org/dev/
7. **NASA UAV & Urban Air Mobility Research Portal**, *Guidance, Navigation, Control & Autonomy Resources*.
   Available: https://www.nasa.gov/aeroresearch/uam/
8. • **Coursera**, *"Modern Robotics: Dynamics, Control, and Estimation,"* Northwestern University.
   Available: https://www.coursera.org/specializations/modern-robotics
9. **NPTEL**, *"Flight Dynamics and Control,"* **Prof. A. K. Ghosh**, IIT Kanpur.
   Available: https://nptel.ac.in/courses/101104014/
10. **NPTEL**, *"Control Engineering,"* **Prof. S. D. Agashe**, IIT Bombay.
    Available: https://nptel.ac.in/courses/108101037/
11. **NPTEL**, *"Introduction to UAV Systems,"* **Prof. H. V. Sridhar**, IISc Bengaluru.
    Available: https://nptel.ac.in/courses/101104061/
12. **MIT OpenCourseWare**, *"Flight Vehicle Dynamics,"* MIT Department of Aeronautics & Astronautics.
    Available: https://ocw.mit.edu/courses/16-333-aircraft-vehicle-dynamics/
13. **PX4 Autopilot Documentation**, *Official Open-Source UAV Flight Control Stack*.
    Available: https://docs.px4.io/
14. **ArduPilot Dev Guide**, *Open-Source Autopilot for Multirotors, Fixed-Wing, and VTOL UAVs*.
    Available: https://ardupilot.org/dev/

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

Class tests	:	05 Marks
Task based group activity	:	05 Marks
Case Studies	:	05 Marks
Regularity and Active Participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% of the syllabus

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20-30% weightage, and the syllabus covered from MSE to ESE carrying 70-80% weightage.

Course Type	Course Code	Course Name	Credits
HMP	HMPAN801	Honours/Minor Mini Project	02

Program Outcomes addressed:

1. PO1 : Engineering knowledge
2. PO2 : Problem Analysis
3. PO3 : Design/Development of Solutions
4. PO4 : Conduct investigations of complex problems
5. PO5 : Modern Tool Usage
6. PO6 : The Engineer & World
7. PO7 : Ethics
8. PO8 : Individual & team work
9. PO9 : Communication
10. PO10: Project Management & Finance
11. PO11: Life-long learning

Course Objectives

1. To guide students in identifying specialization-domain problems
2.. To explore advanced solutions using emerging technologies and specialized tools.
3. To develop research aptitude, innovation mindset, entrepreneurship potential, and lifelong learning skills.
4.. To foster self-directed learning, domain-specific competency, and collaboration.

Course Outcomes

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

CO1: Identify and articulate a domain-relevant societal, industrial, or research problem using literature review and analysis.

CO2: Apply engineering principles and specialized tools to design innovative and feasible technical solutions.

CO3: Conduct investigations, simulations, or experiments to validate the proposed solution using appropriate methods.

CO4: Evaluate the solution considering sustainability, ethics, feasibility, and potential for commercialization or IP.

CO5: Demonstrate teamwork, project management, and professional technical communication through reports and presentations.

CO6: Engage in self-directed learning and continuous improvement to enhance domain expertise and professional growth.

Guidelines for the Mini Project

• Projects should align with the Honors/Minor specialization domain

Mini project may be carried out in one or more form of following:

Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software development, integration of software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc.

• Students must form groups of 3 to 4 members.

• Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty. **• An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted.** **• Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor.** **• Faculty input should emphasize guiding by faculty and self-learning by group members.** **• Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model.** **• The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report.** **• With the focus on self-learning, innovation, research orientation, addressing societal and industry challenges, and developing entrepreneurship qualities among students, the Mini Project should reflect appropriate depth, technical sophistication, specialization-domain relevance, and quality. Students are encouraged to adopt an innovative approach, explore emerging technologies, and demonstrate prototype development, domain-specific research outputs, or commercialization potential, rather than limiting to basic model implementation.**
In-Semester Continuous Assessment and End-Semester Examination Guidelines
• The coordinating Head of the Department will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations in a semester. **• Assessment will be based on individual contributions, understanding, and responses to questions asked.** **• Continuous Assessment marks distribution (50 marks):** **o 20 marks for the Topic Approval Presentation in front of the progress monitoring committee** **o 20 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee** **o 10 marks for regularity & active participation** **The review/progress monitoring committee will assess projects based on the following criteria.** **• Theoretical solution completion, including component/system selection/design of software solution and cost analysis.** **• Two reviews will occur:** **o The first review will focus on finalizing the problem statement (topic approval).** **o Second review will assess the progress of building a working prototype. (Mid Semester Presentation)** **In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:** **1. Quality of survey and need identification aligned with specialization or societal/industry relevance.** **2. Clarity and innovativeness in problem definition and solution Clarity, originality, and innovativeness in problem definition, solution approach, and use of advanced tools/techniques.** **3. Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.** **4. Completeness and full functioning of the working model.** **5. Effective use of skill sets and engineering norms.** **6. Verification & validation of the solutions/test cases.** **7. Individual contributions to the group.** **8. Clarity in written and oral communication.**

9. Participation in research paper presentation, domain-specific competitions, hackathons, demonstrations, start-up pitching, or innovation challenges.

End-Semester Examination (50 marks):

1. **Presentation and demonstration to internal and external examiners: 20 marks.**
2. **Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.**