Syllabi
Third Year
Data Analytics and Artificial Intelligence

Course Type	Course Code	Course Name	Credits
HMC	HMCDA501	ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING	3

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:

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Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design / Development of Solutions
4. PO5: Engineering Tool Usage
5. PO8: Individual and Collaborative Team Work
6. PO11: Life Long Learning

Course Objectives:

1. To get acquainted with the history, basic concepts and applications in AI & ML in various domains.
2. To get familiarize with search algorithms, regression and classification models, clustering and ensemble methods.
3. To comprehend various optimization methods for improving the accuracy score of the model.

Module	Details	Hrs.
	Course Introduction This course provides a comprehensive introduction to Artificial Intelligence (AI) and Machine Learning (ML), focusing on key concepts, algorithms, and applications. To have an ability to AI techniques like search algorithms, decision trees, and optimization methods, alongside ML models such as supervised, unsupervised, and reinforcement learning. Emphasis is placed on real-world applications, such as predictive maintenance, fault detection, process optimization, and data analysis which are common problems in service industries.	**01**

01.	**Introduction to AI & ML** ***Learning Objective:*** *To explore the history, applications, its comparison with Data Science, its relevance to Mechanical Engineering, and foundational concepts in Machine Learning and AI techniques.* **Contents:** History of AI, Comparison of AI with Data Science, Need of AI in Mechanical Engineering, Introduction to Machine Learning. Basics: Reasoning, problem solving, Knowledge representation, Planning, Learning, Perception, Motion, and manipulation. Approaches to AI: Cybernetics and brain simulation, Symbolic, Sub-symbolic, Agents and Environment: Types of AI agents, structure, nature of environment. ***Self-Learning Topics:*** -- ***Learning Outcomes:*** *A learner will be able to* *LO 1.1: Identify appropriate type of agent, PEAS parameters and task environment for the given problem (P.I.- 2.1.2)* *LO 1.2: Solve the given problem using different types of agents. (P.I.- 3.2.1)* *LO 1.3: Select the optimal solution for the given problem based on the requirement of problem. (P.I. - 3.2.2)* *LO 1.4: Identify the objectives of real world problem by considering the PEAS parameters. (P.I. - 2.1.1)*	**4-6**
02.	**Problem Solving with Applications** ***Learning Objective:*** *1. To demonstrate the difference between uninformed and informed search algorithms,* *2. To explore the fundamentals of supervised, unsupervised, and reinforcement learning.* **Contents:** Uninformed Search: Breadth First Search, Depth First Search. Informed Search: Heuristic Search, Best First Search Branch and Bound. Introduction to Learning – Supervised, Unsupervised, Reinforcement. ***Self-Learning Topics:*** -- ***Learning Outcomes:*** *A learner will be able to* *LO 2.1: Compare and contrast Breadth-First Search and Depth-First Search in terms of their performance, use cases, and memory requirements. (P.I. - 2.2.4)* *LO 2.2: Select the optimal searching methods to get the solution to the engineering problems (P.I. - 3.3.1)* *LO 2.3: Determine the objectives of the real world problem, select best search methods to arrive at the desired goal. (P.I. - 3.1.6)*	**6-8**

	LO 2.4: Solve the problems using fundamental Machine learning techniques (Supervised, Unsupervised, and Reinforcement Learning), including their use cases, strengths, and challenges. (P. I. - 1.7.1) (new) *LO 2.5: Apply the fundamental mathematical techniques to solve the problems using Supervised and Unsupervised Machine Learning methods (P.I. - 1.1.1)* *LO 2.6: Identify the existing informed and uninformed search methods to solve the problem by justifying the underlying assumptions in it. (P.I. 2.2.3)*	
03.	**Classification and Regression**	**7-9**
	Learning Objective: *To demonstrate the ability of applying machine learning algorithms for the classification and prediction tasks.*	
	Contents: Decision Tree (non-parametric classification), Entropy reduction and information gain, Gini Index, KNN (non-parametric classification), Support Vector Machine (SVM) Algorithm (for both classification and regression), Naive Bayes Algorithm (for classification) Regression: Linear Regression, Logistic Regression	
	Self-Learning Topics: ---	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Compare and contrast the results of the decision trees by solving them with ID3 and Gini index algorithm. (P.I. - 2.2.4)* *LO 3.2: Apply the fundamental mathematical knowledge to calculate the Entropy **Reduction** and **Information Gain** to construct decision trees. (P. I. - 1.1.1)* *LO 3.3: Apply the process of **KNN for clustering or classification**, based on your design objectives and functional requirements. (P.I. – 3.1.6)* *LO 3.4: Apply the advanced mathematical techniques to model **SVM for classification**, including the concepts of hyperplanes, margin maximization, and support vectors. (P.I. - 1.1.2)* *LO 3.5: Apply Naive Bayes technique in classification tasks. (P.I. - 2.4.1)* *LO 3.6: Apply **linear regression or logistic regression**, on an engineering problem by making the formal decision based on their their application, assumptions, and output interpretations. (P.I. – 3.3.1)*	
04.	**Clustering and Ensemble Methods**	**7-9**
	Learning Objectives: *To explore clustering techniques and ensemble methods for improved data analysis and prediction.*	
	Contents: Hierarchical Clustering, K-Means, K mediod, DBScan Ensemble Methods: Bagging, Boosting (Xgboost, Adaboost), Random Forest	
	Self-Learning Topics: --	
	Learning Outcomes:	
	A learner will be able to *LO 4.1: Apply mathematical techniques on the given data to form a dendogram*	

	using divisive and aggleromative approach. (P.I. - 1.1.1) *LO 4.2: Apply the mathematical techniques to a clustering problems using K – means and K-mediods. (P.I. - 2.4.1)* *LO 4.3: Apply the mathematical techniques in DBScan Algorithm to determine the density of outliers. (P.I. - 1.1.2)* *LO 4.4: Recognize the need of clustering in Unsupervised engineering problems. (P.I. - 3.1.1)* *LO 4.5: Identify suitable clustering techniques and ensemble methods to solve an unsupervised machine learning problem. (P.I. - 3.2.3)* *LO 4.6: Compare various types of Ensemble methods based on their strengths and limitations. (P.I. - 2.2.4)*	
05.	**Optimization** ***Learning Objective/s:*** *To explore the unconstrained and constrained optimization techniques to improve the accuracy score of the machine learning model* **Contents:** Introduction to optimization problems, Unconstrained optimization techniques (gradient descent, Newton's method), Constrained optimization and Lagrange multipliers, Convex optimization and its importance in machine learning, Optimization algorithms in machine learning (e.g., stochastic gradient descent, Adam), Applications of optimization in data science (e.g., parameter tuning in machine learning models, portfolio optimization) ***Self-Learning Topics:*** -- ***Learning Outcomes :*** *A learner will be able to* *LO 5.1: Compare and contrast Gradient Descent and Newton's Method, discussing their computational efficiency, convergence rates, and application scenarios. (P.I. - 2.2.4)* *LO 5.2: Apply Lagrange multipliers to solve optimization problems with equality constraints, and interpret the significance of Lagrange multipliers in terms of constraint sensitivities. (P.I. - 1.1.1)* *LO 5.3: Demonstrate the role of convex optimization in machine learning, emphasizing how convexity allows for guaranteed convergence to global optima (P.I. - 3.3.1)* *LO 5.4: Identify suitable criterion (SGD or Adam) in terms of their convergence speed, stability, and performance on various machine learning tasks. (P.I. - 3.2.3)* *LO 5.5: List the various types of optimization techniques to improve the model efficiency (P.I. - 2.2.3)* *LO 5.6: Explore real-world examples of optimization in data science and machine learning, including image classification, recommendation systems, and predictive modeling. (P.I. - 1.1.2, 11.3.1)*	**7-9**
06.	**Applications** ***Learning Objective/s:*** *To explore the applications of AI in Human-Machine Interaction, predictive maintenance, fault detection, system optimization, and material inspection for*	**6-8**

	enhanced industrial and engineering processes.	
	Contents: Human Machine Interaction, Predictive Maintenance and Health Management, Fault Detection, Dynamic System Order Reduction, Image based part classification, Process Optimization, Material Inspection, Tuning of control algorithms.	
	Self-Learning Topics: *Applications of Machine Learning in Mechanical Engineering domain*	
	Learning Outcomes:	
	A learner will be able to *LO 6.2: Apply mathematical and statistical techniques on predictive maintenance models (e.g., time series analysis, machine learning algorithms) used to predict failure patterns in machinery and equipment. (P.I. – 1.1.2)* *LO 6.3: Compare and contrast different machine learning algorithms (e.g., convolutional neural networks, k-nearest neighbors) for improving the accuracy and robustness of image-based part classification systems. (P.I. – 2.2.4)* *LO 6.4: Evaluate the effectiveness of sensor technologies (e.g., infrared, laser-based) and AI algorithms in enhancing the accuracy and speed of material inspection processes. (P.I. – 3.2.3)* *LO 6.5: Apply the fundamental statistical techniques in process optimization. (P.I. – 1.1.1)* *LO 6.6: Explore the research gaps in the field of Mechanical Engineering domain and find the best suited tools and algorithms for problem solving in a team.(P.I. - 2.1.1 , 3.2.2 , 5.2.2 , 8.3.1 , 11.1.2)*	
	Course Conclusion	**01**
	Total	**45**

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.
1.7.1	Apply theory and principles of computer science engineering to solve an engineering problem.
2.1.1	Articulate problem statements and identify objectives.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
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.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
3.1.1	Recognize that need analysis is key to good problem definition.
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.
3.2.2	Build models/prototypes to develop diverse set of design solutions.
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.
5.2.2	Demonstrate proficiency in using discipline specific tools.
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.
11.3.1	Source and comprehend technical literature and other credible sources of information.

Course Outcomes: A learner will be able to -

1. Demonstrate the basics of AIML along with its history, need and applications in various domains. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4)*
2. Apply search methods on different types of Machine Learning methods. *(LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 2.6)*
3. Identify the type of problem and apply suitable classification or regression techniques to solve the identified problem. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5, LO 3.6)*
4. Apply the clustering and ensemble methods to improve accuracy, reduce overfitting, and provide more robust results. *(LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 4.6)*
5. Apply the optimization techniques to improve the accuracy of the model. *(LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 5.5, LO 5.6)*
6. Identify the applications of AI in Mechanical Engineering field and apply AI and ML techniques to identify the best method for the particular application. *(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
HMCDA501.1	--	3	3	--	--	--	--	--	--	--	--
HMCDA501.2	3	3	3	--	--	--	--	--	--	--	--
HMCDA501.3	3	3	3	--	--	--	--	--	--	--	--
HMCDA501.4	3	3	3	--	--	--	--	--	--	--	--
HMCDA501.5	3	3	3	--	--	--	--	--	--	--	2
HMCDA501.6	3	3	3	--	2	--	--	2	--	--	2
Average	**3**	**3**	**3**	**--**	**2**	**--**	**--**	**2**	**--**	**--**	**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. "Artificial Intelligence: A Modern Approach" by Stuart Russell and Peter Norvig, 3rd Edition, 2015, Prentice Hall.
2. "Machine Learning: A Probabilistic Perspective" by Kevin P. Murphy, 2012, MIT Press.
3. "Convex Optimization" by Stephen Boyd and Lieven Vandenberghe, First Edition, 2004, Cambridge University Press.

Reference Books :

1. "Predictive Maintenance in Dynamic Systems" by Edwin Lughofer and Moamar Sayed-Mouchaweh, 2019, Springer .
2. "Modern control engineering" by Katsuhiko Ogata , Fifth Edition , 2010 , Prentice Hall
3. "Deep Learning" by Ian Goodfellow, Yoshua Benjio and Aaron Courville, 2016,Cambridge, Massachusetts : The MIT Press.
4. Human-Machine Interaction: Fundamentals and Applications, Andrea Leitner, Jürgen Ziegler, 1st Edition, 2021, Springer.

Other Resources :

1. NPTEL Course: An introduction to Artificial Intelligence By Prof. Mausam, Department of Computer Engineering, IIT Delhi :-Web link- An Introduction to Artificial Intelligence - Course

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment – Theory (20 Marks)

One MCQ test as per GATE exam pattern/ level	:	05 Marks
One Class test	:	05 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 (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
HMC	HMCDA602	FOUNDATIONS OF DATA SCIENCE	03

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

Pre-requisite :

1. MEPCC405: Engineering Mathematics-IV

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. PO11: Life-Long Learning

Course Objectives :

1. To get acquainted with linear algebra, statistical techniques, probability distributions and their applications in machine learning applications.
2. To comprehend quantitative and qualitative data types which can be used effectively to visualize data using various plots.
3. To impart the knowledge of data structures, basic sorting, search and optimization algorithms for efficient problem-solving.

Module	Details	Hrs
	Course Introduction This course provides a comprehensive introduction to key concepts in mathematics and computer science for data analysis and machine learning. Topics include linear algebra, graphs, statistics, probability, data structures, and algorithms. Practical applications, such as PCA, recommender systems, and optimization problems, are explored to strengthen your analytical skills.	**01**
01.	**Introduction to Linear Algebra** ***Learning Objective/s:*** *To demonstrate the techniques of linear algebra used in Machine Learning algorithms.*	**5-7**

	Contents: Vectors and Matrices, Solving Linear equations, The four Fundamental Subspaces, Eigenvalues and Eigen Vectors, The Singular Value Decomposition (SVD), Cholesky, Eigen decomposition, and Diagonalization, Applications of linear algebra in machine learning (e.g., PCA, SVD in recommender systems) ***Self-Learning Topics:*** --- ***Learning Outcomes :*** *A learner will be able to* *LO 1.1: Compute eigenvalues and eigenvectors, vector subspaces and apply them to various mathematical problems. (P.I. 1.1.2)* *LO 1.2: Apply linear algebra techniques, such as PCA and SVD, to real-world machine learning problems, including recommender systems (P.I. 2.4.1)* *LO 1.3: Compare the solutions of Singular Value Decomposition (SVD) and Cholesky decomposition. (P.I. 2.2.4)* *LO 1.4: Apply concepts of vectors and matrices in solving linear equations. (P.I. 1.1.1)*	
02.	**Introduction to Graphs** ***Learning Objective/s:*** *To demonstrate the use of visualization techniques used to represent the quantitative and qualitative data.* **Contents:** Quantitative vs. Qualitative data, Types of Quantitative data: Continuous data, Discrete data, Types of Qualitative data: Categorical data, Binary data, Ordinary data, plotting data using Bar graph, Pie chart, Histogram, Stem and Leaf plot, Dot plot, Scatter plot, Time-series graph, Exponential graph, Logarithmic graph, Trigonometric graph, Frequency distribution graph ***Self-Learning Topics:*** --- ***Learning Outcomes :*** *A learner will be able to* *LO 2.1: Identify various graphical techniques to represent quantitative and qualitative data. (P.I. 2.2.3)* *LO 2.2: Apply various data visualization techniques, including bar graphs, pie charts, histograms, and scatter plots. (P.I. 1.1.1)* *LO 2.3: Create advanced plots such as stem-and-leaf plots, time-series graphs, exponential graphs, logarithmic graphs and arrive at solution. (P.I. 4.3.3)* *LO 2.4: Apply the advanced mathematical techniques to represent data using frequency distribution graphs. (P.I. 1.1.2)* *LO 2.5: Compare and contrast the visualization techniques with reference to the type of data. (P.I. 2.2.4)* *LO 2.6: Analyze the data, plot various graphs and reach the appropriate conclusions. (P.I. 4.3.4)*	**6-8**

03.	**Statistics** ***Learning Objective/s:*** *To analyze data using statistical techniques and to plot the data using statistical diagrams.* **Contents:** Measures of central tendency: mean, median, mode. Measurement of variability and dispersion: Standard deviation, standard error, variance, range. Measure of shape: skewness, kurtosis Statistical diagram: scattered diagram, histogram, pie charts, and measure of association between two variables. Correlation: Karl Pearson's Coefficient of correlation and its mathematical properties, Spearman's Rank correlation and its interpretations ***Self-Learning Topics:*** *Mean , Mode and Median* ***Learning Outcomes :*** *A learner will be able to* *LO 3.1: Calculate measures of central tendency (mean, median, mode) to summarize data. (P.I. 1.1.1)* *LO 3.2: Evaluate variability and dispersion using standard deviation, standard error, variance, and range. (P.I. 1.1.2)* *LO 3.3: Identify the suitable criterion to select the shape of the data distribution curves. (P.I. 3.2.3)* *LO 3.4: Analyze the data by plotting various statistical diagrams such as scatter diagrams, histograms, and pie charts to reach at appropriate conclusions. (P.I. 4.3.4)* *LO 3.5: Identify the mathematical techniques to evaluate the relationship between two variables using correlation techniques. (P.I. 2.1.3)* *LO 3.6: Compare and contrast Karl Pearson's coefficient of correlation and Spearman's rank correlation. (P.I. 2.2.4)*	**8-10**
04.	**Probability** ***Learning Objective/s:*** *To demonstrate the use of basic probability concepts and various probability distribution techniques in machine learning and data science.* **Contents:** Introduction to Probability for Machine Learning, Construction of a Probability Space, Discrete and Continuous Probabilities, Sum Rule, Product Rule, and Bayes' Theorem. Probability distributions: Binomial, Gaussian, Poisson, Normal and Chi square. Applications of probability and statistics in data science (e.g., A/B testing, Bayesian modelling). ***Self-Learning Topics:***	**6-8**

	Basics of Probability	
	Learning Outcomes : *A learner will be able to* *LO 4.1: Demonstrate the fundamentals of probability and its significance in machine learning. (P.I. 1.1.1)* *LO 4.2: Apply the Sum Rule, Product Rule, and Bayes' Theorem to solve the machine learning problem. (P.I. 1.1.2)* *LO 4.3: Identify key probability distributions, including binomial, Gaussian, Poisson, normal, and chi-square distributions. (P.I. 2.2.3)* *LO 4.4: Apply basic mathematical and computational methods to model the engineering problem using Baysian probabilities. (P.I. 2.4.1)* *LO 4.5: Develop a solid foundation for incorporating probability and statistics into data analysis and machine learning applications using modern tools for future work. (P.I. 3.2.2, 5.1.2 ,11.2.2)*	
05.	**Data Structures** ***Learning Objectives:*** *To demonstrate the basics of arrays , linked lists , trees and graphs .*	**6-8**
	Basics of Arrays: Understanding how to store and manipulate data efficiently, Linked Lists: Exploring different types (singly, doubly, circular) and basic operations like insertion, deletion, and searching, Stacks and Queues: Fundamentals of these data structures and their common operations, Trees: Introduction to binary trees and binary search trees, along with basic operations, Graphs: Basics of representation and traversal algorithms like BFS and DFS, Hash Tables: Understanding the concept of hashing for efficient data storage and retrieval.	
	Self-Learning Topics: -- ***Learning Outcomes :*** *A learner will be able to* *LO 5.1: Demonstrate the basics of arrays, including efficient data storage and manipulation techniques. (P.I. 1.1.1)* *LO 5.2: Perform basic operations (insertion, deletion, searching) on different types of linked lists (singly, doubly, and circular). (P.I. 1.7.1 (New))* *LO 5.3: Build the decision trees, binary trees and graphs for the given engineering problem. (P.I. 3.2.2)* *LO 5.4: Compare the structure and operations of DFS and BFS to generate the search tree. (P.I. 2.2.4)* *LO 5.5: Identify the appropriate method (like stack or queue) to solve the engineering problem. (P.I. 2.2.3)* *LO 5.6: Apply formal decision making tools to select the optimum tree based on some criterion (like lowest cost method, etc.) (P.I. 3.3.1)*	
06.	**Algorithms for Data Structures** ***Learning Objective/s:*** *To apply basic sorting, search and optimization algorithms for efficient problem-solving.*	**6-8**
	Contents:	

	Sorting and Searching: Introduction to basic sorting algorithms like bubble sort, selection sort, and searching algorithms like linear search, Recursion: Basic understanding of recursive algorithms and their application in problem-solving, Dynamic Programming: Introduction to the concept of dynamic programming and its application in solving problems efficiently, Greedy Algorithms: Basics of greedy algorithms and their application in solving optimization problems, Graph Algorithms: Basic understanding of algorithms like Dijkstra's and BellmanFord for shortest path problems	
	Self-Learning Topics: --	
	Learning Outcomes : *A learner will be able to* *LO 6.1: Use basic sorting algorithms, such as bubble sort, selection sort and linear search to solve the classification problems. (P.I. 2.5.2) (New)* *LO 6.2: Compare recursion with other methods in problem-solving and understand its role in algorithmic design. (P.I. 2.2.4)* *LO 6.3: Use of fundamentals of mathematics in dynamic programming to solve complex problems efficiently. (P.I. 1.1.1)* *LO 6.4: Implement the principles of greedy algorithms to optimization problems. (P.I. 3.3.1)* *LO 6.5: Identify and implement Dijkstra's and Bellman-Ford for solving shortest path problems to create alternate design models. (P.I. 3.2.3)* *LO 6.6: Develop problem-solving skills in machine learning using statistical and optimization techniques using modern tools. (P.I. 1.1.2,5.1.2,11.2.2)*	
	Course Conclusion	**01**
	Total	**45**

Performance Indicators:

<u>**P.I. No.**</u>	<u>**P.I. Statement**</u>
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
1.7.1	Apply theory and principles of computer science engineering to solve an engineering problem. (new)
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
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.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
2.5.2	Identifies processes/modules/algorithms of a computer based system and parameters to solve a Problem. (new)
3.2.2	Build models/prototypes to develop diverse set of design solutions.

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.
4.3.3 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.
5.1.2 Create/adapt/modify/extend tools and techniques to solve engineering problems.

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. Apply the techniques from linear algebra to solve linear equations and to decompose the matrix. (*LO 1.1, LO 1.2, LO 1.3, LO 1.4*)
2. Visualize the quantitative and qualitative data by identifying appropriate visualization techniques. (*LO 2.1, LO 2.2, LO 2.3, LO 2.4 , LO 2.5, LO 2.6*)
3. Apply the statistical techniques to solve the engineering problems. (*LO 3.1, LO 3.2, LO 3.3, LO 3.4 , LO 3.5, LO 3.6*)
4. Apply the probability distribution techniques to an engineering problem to get the optimal results. (*LO 4.1, LO 4.2, LO 4.3, LO 4.4 , LO 4.5*)
5. Apply the basics of arrays, linked lists, trees and graphs methods to get optimal decisions. (*LO 5.1, LO 5.2, LO 5.3, LO 5.4 , LO 5.5, LO 5.6*)
6. Apply basic sorting, search and optimization algorithms for efficient problem-solving. (*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
HMCDA602.1	3	3	--	--	--	--	--	--	--	--	--
HMCDA602.2	3	3	--	3	--	--	--	--	--	--	--
HMCDA602.3	3	3	2	2	--	--	--	--	--	--	--
HMCDA602.4	3	3	2	--	2	--	--	--	--	--	2
HMCDA602.5	3	3	3	--	--	--	--	--	--	--	--
HMCDA602.6	3	3	3	--	2	--	--	--	--	--	2
Average	**3**	**3**	**3**	**3**	**2**	**--**	**--**	**--**	**--**	**--**	**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. Advanced Engineering Mathematics, H. K. Dass, Twenty-first Revised Edition, 2013, S.Chand and Company Ltd.
2. Data Structures through C in Depth, S. K Srivastava, Deepali Srivastava, 5th Edition, 2011, BPB Publications.
3. "Business Statistics" by D.N. Elhance, Veerendra Khatau, and B.K. Bhattacharyya, 2020, Taxmann Publications Pvt. Ltd.

Reference Books :

1. Higher Engineering Mathematics, Dr. B. S. Grewal, Forty Second Edition, 2017, Khanna Publication.
2. Probability, Statistics and Random Processes, T Veerarajan, Second Edition, 2004, Tata McGraw-Hill Publishing Company Ltd.
3. Fundamentals of Data Structures, Ellis Horowitz, Sartaj Sahni, 5th Edition, 2010, Galgotia Publications.
4. An introduction to data structures with applications, Jean Paul Tremblay, Paul G. Sorenson; 3rd Edition, 1984, Tata McGraw-Hill.
5. "Statistics for Business and Economics" by Paul Newbold, William L. Carver, and Betty Thorne, 6th Edition, 2007, Pearson Prentice Hall

Other Resources :

1. NPTEL Course: Probability and Statistics By Prof. Somesh Kumar, Department of Mathematics, IIT Kharagpur :-Web link- https://onlinecourses.nptel.ac.in/noc21_ma74/preview
2. NPTEL Course: Data Structures and Algorithms By Prof. Naveen Garg, Department of Computer Science and Engineering , IIT Delhi :-
   Web link- https://archive.nptel.ac.in/courses/106/102/106102064/#

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

One MCQ test as per GATE exam pattern/ level	:	05 Marks
One Class test	:	05 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

Syllabi
Third Year
Additive Manufacturing

Course Type	Course Code	Course Name	Credits
HMC	HMCAM501	CAD MODELING	03

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. ESL204 Engineering Graphics Laboratory

Program Outcomes addressed:

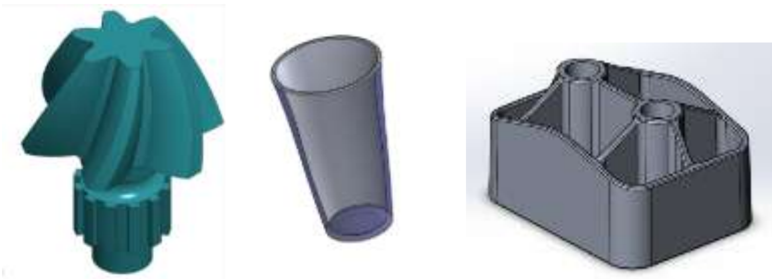
1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/Development of Solutions
4. PO5: Engineering tool usage
5. PO8: Individual and Collaborative Team work
6. PO9: Communication

Course Objectives:

1. To familiarize students with basic concepts of CAD modeling.
2. To make students acquaint with feature based CAD modeling.
3. To prepare students to use manipulations and modification tools in CAD modeling.
4. To enable students to build CAD assembly and Design for Assembly.
5. To instruct students to use drafting, rendering and visualization tools to prepare CAD representation and communication purposes.

Module	Details	Hrs.
	Course Introduction CAD Modeling course introduces students to the essential principles and techniques used to create digital models of physical objects and designs. It equips students with essential skills that are vital in modern industries to design product more efficiently, reduce errors, generate and validate innovations at faster rate, and effectively communicate user's ideas. With the increasing reliance on digital design, CAD proficiency is a powerful and highly sought-after skill in today's workforce.	**01**
01.	**Introduction to CAD modeling basics.** ***Learning Objective:***	**5-7**

	To get acquainted with the evolution, role, applications of CAD Modeling, and creating and modifying 2D sketches. **Contents:** Evolution of CAD modeling, role of CAD tools in product development, applications of CAD modeling across various disciplines, introduction to 2D and 3D CAD modeling, CAD software and hardware requirements, overview of CAD software, introduction to the user interface and basic commands, creating and modifying 2D sketches, working with dimensions and constraints to control geometry. ***Self-Learning Topics:*** *Discipline specific CAD software* ***Learning Outcomes:*** *A learner will be able to* *LO 1.1: State benefits of CAD modeling in product design and development. (PI 1.3.1)* *LO 1.2: Summarize hardware and software requirements for running CAD applications effectively. (PI 1.4.1)* *LO 1.3: Identify the evolution of CAD modeling from its early stages to modern-day applications including how advancements in CAD tools have influenced product development. (PI 2.1.1)* *LO 1.4: Analyze the role of CAD in the entire product development lifecycle, from concept to production, highlighting the key benefits of using CAD in design, prototyping, and manufacturing (PI 2.1.2)* *LO 1.5: Interpret the effect of dimensions and constraints in controlling the geometry of a 2D sketch in CAD (PI 2.1.3)* *LO 1.6: Apply suitable constrains to a given drawing. (PI 2.2.2)*	
02.	**Parametric and Feature-Based CAD Modeling** ***Learning Objective:*** *To get familiarize with the parametric CAD modeling, techniques in CAD Modeling, feature-based CAD Modeling, its advantages, limitations, and applications, CAD workflow and creation and modification of simple CAD parts using features.* **Contents:** Introduction to parametric and non-parametric CAD design, techniques of CAD modeling - Wire Frame Modeling, Solid Modeling, Surface Modeling, and feature based modeling. Applications of feature based modeling in CAD, various features and their significance in CAD modeling, creating CAD models with basic parametric features like, extrude, revolve, cut, fillet, etc., editing features to modify CAD parts, applying materials and textures to 3D CAD models. ***Self-Learning Topics:*** *Constructive solid geometry* ***Learning Outcomes:*** *A learner will be able to* *LO 2.1: State key advantages of feature based CAD modeling. (PI 1.3.1)* *LO 2.2: Compare parametric and non-parametric CAD modeling. (PI 1.4.1)* *LO 2.3: Identify the significance of solid CAD models, over wireframe and surface CAD models. (PI 2.1.2)* *LO 2.4: Assess characteristics of feature based CAD modeling including their applications in product design. (PI 2.1.3)*	**6-8**

	LO 2.5: Group various features of a CAD tool, as per their characteristics. (PI 2.2.2)	
03.	**Advanced Level Feature-Based CAD Modeling** ***Learning Objective:*** *To get acquainted with advance CAD modeling features, use of 3D sketches, surface CAD modeling, history based modeling, parametric representation of curves in CAD systems to create and modify complex CAD parts.*	**9-11**
	Contents: Advanced part creation techniques: lofts, sweeps, and ribs etc., using patterns and mirroring in design, working with complex geometrical features (drafts, shells, threads), CAD work flow, introduction to surface modeling and creating curved surfaces, use of 3D sketches in development of CAD part, managing design changes and history-based modeling, Role of parametric representation of curves in CAD systems, applications of curves in CAD systems, parametric representation of analytical and synthetic curves, Bezier curves, Hermite curves, B-spline curves, introduction to surface representations.	
	Self-Learning Topics: *Boundary Representations*	
	Learning Outcomes: *A learner will be able to* *LO 3.1: State reasons for using parametric form of curves in CAD Systems. (PI 1.3.1)* *LO 3.2: Write any four analytical curves and their respective mathematical equations. (PI 1.4.1)* *LO 3.3: Derive the parametric equation of circle and line. (PI 2.1.2)* *LO 3.4: The coordinates of four control points are P0 (1,3), P1(5,6), P2(6,0) and P3(7,2). Determine points on the curve for, u=0, 0.2, 0.4, 0.6, 0.8, and 1. plot the curve (PI 2.2.2)* *LO 3.5: For the CAD model shown in figure, determine various CAD workflow approaches based on choice and sequence of features. (PI 2.2.4)*  *LO 3.6: A task based group activity, before MSE. (Part I) (PI 3.1.6, 3.2.2, 5.1.1, 5.1.2, 8.3.1, 9.1.3, 9.3.1, 9.3.2)* *To create CAD models of all components or parts (minimum 6 parts per group, excluding standard parts, max 4 students in one group), in a system or structure fulfilling following aspects,* *A. Create sketches during CAD modeling process for each CAD part, by selecting 2D sketching and modifying tools, dimensions and constraints, etc.* *B. Demonstrate proficiency in identifying basic and advance level features, in appropriate sequence and use manipulation commands to create and modify each CAD part.* *C. Develop diverse set of CAD work flow for the same CAD part, using variety of combination and sequence of features and modification commands.*	

	D. Demonstrate use of history-based modeling to track and modify CAD parts at any stage of the design process. *E. Create 3D sketches, synthetic curves and surface CAD modeling (if needed), to define geometries and non-planar features.* *F. Prepare a document/ report of the activity and present the same for one to one discussion/ communication. (Actual working demonstration, report in soft medium, presentation and group wise discussion of the activity)*	
04.	**Geometric Transformations** ***Learning Objectives:*** *To understand the role and importance of geometric transformations in CAD modeling and similar modeling tools across various sectors* **Contents:** Introduction to geometric transformations, need of modification and manipulations tools in CAD modeling, applications of geometric transformations, types of 2D and 3D transformations: - translation, scaling, reflection, rotation, shearing, in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Case studies on applications of geometric transformations in various CAD and similar tools across various industrial sectors. ***Self-Learning Topics:*** *Geometric transformations in 3D printing software packages.* ***Learning Outcomes:*** *A learner will be able to* *LO 4.1: State importance of homogeneous representations of transformation matrix. (PI 1.3.1)* *LO 4.2: Convert a non-homogeneous transformation matrix to homogeneous transformation matrix. (PI 1.4.1)* *LO 4.3: Apply concatenation rule of transformations, combining multiple transformations to fulfill given modification sequence. (PI 2.1.1)* *LO 4.4: Determine transformation matrix and final coordinates of a geometry bounded by coordinates (2,1), (3,4), (7,7) and (10,3), when rotated about point (8,8) by 30° in cw direction and scaled by 2 units in X direction and 3 units in Y direction w.r.t. point (8,8). (PI 2.1.2)* *LO 4.5: Identify, read and summarize one case study/ an article (from a quality journal/ conference/ research paper), where transformations are applied in product geometry modifications and manipulations, across various industrial sectors and present the article contents in a poster format (softcopy). (Article reading and summarization). (PI 2.2.2, 9.1.3)*	**6-8**
05.	**CAD assembly and Design for Assembly** ***Learning Objective/s:*** *To know various assembly methods, appropriate assembly constraints, design for assembly concepts, for parametric assemblies of engineering components, ensuring flexibility and adaptability in the design.* **Contents**: Introduction to CAD assembly, types of assembly in CAD, use of various constrains while creating assembly in CAD modeling tools, creation of parametric assembly of engineering components, creating subassemblies and managing large assemblies, design for assembly (DFA) principles: minimizing part count and simplifying designs, resolving interferences and collisions within assemblies.	**5-7**

	Self-Learning Topics: *Case study on CAD assembly for discipline specific products.*	
	Learning Outcomes : *A learner will be able to* *LO 5.1: State significance of CAD assemblies. (PI 1.3.1)* *LO 5.2: Assess types of CAD assemblies. (PI 1.4.1)* *LO 5.3: Identify role of DFA in CAD assembly process. (PI 2.1.2)* *LO 5.4: Interpret types of assembly constraints to manage relationships between components. (PI 2.1.3)* *LO 5.5: Analyze methods to resolve interferences and collisions issues within an assembly. (PI 2.2.3)*	
06.	**Drafting, Rendering and Visualization**	**6-8**
	Learning Objective/s: To get familiarize with significance of converting 3D CAD models into 2D drawings for manufacturing, assembly, and documentation, various types of drawing, part and assembly drawing with GD&T, basics of rendering and visualization.	
	Contents: Importance of 2D drawing representation of 3D CAD parts and assembly, types of drawings - machine drawing, production drawing (working drawing), part drawing, etc., creation of part and assembly drawing from the CAD parts and assembly, use of GD&T, representing GD&T and other annotations on drawing, introduction to rendering in CAD software, lighting and camera views for presentation, visualizing assemblies and their components in motion (exploded animations).	
	Self-Learning Topics: *Drawings for patents*	
	Learning Outcomes:	
	A learner will be able to *LO 6.1: List types of drawings in CAD. (PI 1.3.1)* *LO 6.2: State importance of CAD drawing as a way of communicating the product details. (PI 1.4.1)* *LO 6.3: Interpret types of geometrical tolerance required for creating production drawings. (PI 2.1.2)* *LO 6.4: Identify key elements of BOM, justify each one. (PI 2.1.3)* *LO 6.5: Analyze various rendering options in CAD tools. (PI 2.2.3)* *LO 6.6: A task based group activity, after MSE. (Part II) (PI 3.1.3, 3.1.6, 5.1.1, 5.1.2, 8.3.1, 9.1.3, 9.3.1, 9.3.2)* *To create CAD assembly of all components from work undertaken in Part I and to create detail and assembly drawing for the same. (minimum 6 parts per group, excluding standard parts, max 4 students in one group), fulfilling following aspects,* *A. Identify and apply assembly constraints and geometric transformations to manage relationships between components* *B. Create parametric assemblies of engineering components.* *C. Use CAD tools to detect, modify and resolve interferences and collisions between components in an assembly, to ensure functional designs.*	

	D. Generate part and assembly drawings from a 3D CAD model and assembly respectively, with dimensions, tolerances, and annotations. *E. Use rendering, lighting and camera and exploded animation tools in CAD software for effective visualization and presentation of 3D models and assemblies.* *F. Prepare a document/ report of the activity and present the same for one to one discussion/ communication. (Actual working demonstration, report in soft medium, presentation and group wise discussion of the activity)*	
	Course Conclusion	**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.
2.2.2	Identify, assemble and evaluate information and resources.
2.2.4	Compare and contrast alternative solution processes to select the best process.
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
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
8.3.1	Present results as a team, with smooth integration of contributions from all individual efforts
9.1.1	Read, understand and interpret technical and non-technical information
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.
9.3.2	Use a variety of media effectively to convey a message in a document or a presentation

Course Outcomes: A learner will be able to -

1. Interpret role of CAD modeling in product development including its applications. (*LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5, LO 1.6*)
2. Use feature based CAD modeling, to create CAD parts, keeping the virtue of CAD workflow. (*LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5, LO 3.6)*
3. Build parametric assemblies of CAD parts using constrains and geometric transformations. (*LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 5.5, LO 6.6)*
4. Generate part and assembly drawings including GD& T and annotations, from 3D CAD data. (*LO 6.1, LO 6.2, LO 6.3, LO 6.4, LO 6.6)*

5. Apply rendering, lighting, camera, and exploded animation tools in CAD software for effective visualization and presentation of 3D models and assemblies. *(LO 3.6, 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
HMCAM501.1	3	3	--	--	--	--	--	--	--	--	--
HMCAM501.2	3	3	3	--	3	--	--	2	3	--	--
HMCAM501.3	3	3	3	--	3	--	--	2	3	--	--
HMCAM501.4	3	3	3	--	3	--	--	2	3	--	--
HMCAM501.5	--	3	3	--	3	--	--	2	3	--	--
Average	**3**	**3**	**3**	**--**	**3**	**--**	**--**	**2**	**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. CAD/CAM Principles and Applications, P. N. Rao, Tata McGraw Hill Publications.
2. CAD / CAM and Automation, Farazdak Haideri , Nirali Prakashan.
3. Machine Drawing by K. L. Narayana, P. Kannaiah and K. Venkata Reddy, New Age International (P) Limited, Publishers

Reference Books :

1. CAD/ CAM, Theory & Practice, Ibrahim Zeid, R. Sivasubramanian, Tata McGraw Hill Publications
2. Machine Drawing, N.D. Bhatt, Charotar Publishing Home Pvt. Ltd.

Other Resources :

1. NPTEL Course: Computer aided Design and Manufacturing I, IIT Guwahati :-Web link https://nptel.ac.in/courses/112102102

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment - Theory-(20 Marks)

Suggested breakup of distribution

A task based group activity, before MSE. (Part I)	:	05 Marks
A task based group activity, after MSE. (Part II)	:	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
HMC	HMCAM602	BIO MODELING	03

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

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. PO9 – Communication
7. PO11 - Lifelong Learning

Course Objectives:

1. Acquaint students with the fundamentals of medical technology, anatomical structures, and medical modeling workflows.
2. Familiarize students with various medical imaging techniques, including CT, CBCT, MRI, and non-contact surface scanning.
3. Impart knowledge on handling, processing, and optimizing medical scan data for medical applications.
4. Enable students to preprocess medical scan data for 3D printing applications in healthcare.
5. Acknowledge the role of additive manufacturing in bio-modeling, including post-processing and sterilization techniques.
6. Integrate case studies to analyze real-world applications, challenges, and advancements in bio-modeling for patient-specific healthcare

Module	Details	Hrs.
	Course Introduction Medical technology plays a pivotal role in modern healthcare, enabling accurate diagnostics, efficient treatment planning, and personalized patient care. This course provides an in-depth exploration of medical imaging, scan data processing, and bio-modeling techniques, with a strong focus on 3D printing applications. Students will gain hands-on	**01**

	experience in handling medical scan data, preprocessing for manufacturing, and integrating additive manufacturing techniques in healthcare. By bridging engineering principles with medical applications, this course equips students with the skills needed to contribute to advancements in patient-specific healthcare solutions.	
01.	**Introduction to Medical Technology** ***Learning Objective:*** *Understand fundamental concepts of medical technology and anatomical structures.*	**4-6**
	Contents: Overview of Medical Technology, Phases of the Medical Modeling Workflow, The human form, Anatomical Structure - basic fundamental terminology and technical terminology	
	Self-Learning Topics: *Biomedical Engineering Applications, Medical Ethics, Regulatory Standards*	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Identify the fundamental concepts and phases of the medical modeling workflow. (PI 1.3.1)* *LO 1.2: Interpret anatomical structure terminology in medical modeling applications. (PI 2.1.2)* *LO 1.3: Summarize the significance of human anatomy in biomedical engineering. (PI 1.2.1)* *LO 1.4: Assess the role of medical modeling in personalized healthcare solutions. (PI 2.3.1)* *LO 1.5: Analyze the significance of anatomical accuracy in 3D medical modeling. (PI 1.4.1)* *LO 1.6: Evaluate the impact of technological advancements on medical modeling workflows. (PI 2.2.3)*	
02.	**Introduction to Medical Imaging** ***Learning Objective:*** *Learn various medical imaging techniques and their applications in medical diagnostics.*	**8-10**
	Contents: **Computed Tomography (CT)** – Principles of CT imaging, X-ray attenuation, image reconstruction, and applications in medical diagnostics.; **Cone Beam CT (CBCT)** – Differences from traditional CT, advantages in dental and maxillofacial imaging, and reconstruction techniques; **Magnetic Resonance (MR)** – Fundamentals of MR imaging, signal acquisition, contrast mechanisms, and clinical uses; **Noncontact Surface Scanning** – Techniques for capturing 3D surface geometry, laser scanning, and structured light scanning, **Medical Scan Data** – Processing medical imaging data, segmentation, and conversion to 3D models; **Point Cloud Data** – Understanding point clouds, data acquisition methods, and applications in medical modeling and 3D reconstruction.	
	Self-Learning Topics: *Advanced Image Reconstruction, Radiomics, AI in Medical Imaging*	

	Learning Outcomes: *A learner will be able to* *LO 2.1: Compare different medical imaging techniques and their principles. (PI 1.3.1)* *LO 2.2: Analyze the advantages and limitations of CT, CBCT, and MR imaging. (PI 2.3.1)* *LO 2.3: Assess the suitability of various imaging methods for different medical applications. (PI 2.2.4)* *LO 2.4: Categorize different medical scan data formats based on their structure, application, and compatibility. (PI 2.1.2)* *LO 2.5: Evaluate the role of segmentation techniques in medical imaging. (PI 2.1.3)* *LO 2.6: Apply fundamental principles of point cloud data acquisition for medical 3D reconstruction. (PI 1.4.1)*	
03.	**Handling and Processing Medical Scan Data** ***Learning Objective:*** *Explore handling, processing, and optimization of medical scan data for analysis and modeling.*	**7-9**
	Contents: Image Pixel Processing– Manipulation of pixel-based medical images, filtering, and enhancement techniques; CT Data Utilization: Practical Example – Step-by-step guide to processing and analyzing CT scan data for medical applications; Point Cloud Data Processing – Techniques for handling and optimizing 3D point cloud data for modeling and analysis; 2D File Formats– Common medical image formats (e.g., DICOM), storage, and usage in diagnostic imaging; Semi-3D Data Representations – Overview of pseudo-3D imaging formats and their role in medical visualization; True 3D formats, File management and exchange	
	Self-Learning Topics: *Deep Learning for Image Processing, DICOM Data Security, Multi-modal Imaging*	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Identify the key principles of image pixel processing and enhancement techniques used in scan data refinement. (PI 1.3.1)* *LO 3.2: Categorize different 2D and 3D medical data formats and assess their relevance in diagnostic imaging. (PI 2.1.2)* *LO 3.3: Examine the significance of DICOM standards in medical imaging data exchange and interoperability. (PI 5.3.2, PI 9.3.1)* *LO 3.4: Design workflows for utilizing semi-3D and true 3D medical data representations in medical visualization. (PI 3.2.1, PI 6.3.1)* *LO 3.5: Utilize point cloud data processing techniques to optimize scan data for high-accuracy 3D modeling. (PI 1.4.1, PI 5.2.2)* *LO 3.6: Assess the challenges of file management, storage, and data exchange for large-scale medical datasets. (6.2.1, PI 11.3.1)* *LO 3.7: Apply fundamental principles of CT data utilization and point cloud optimization for enhanced medical 3D reconstruction. (PI 2.3.1)* *LO 3.8: A Task-Based Group Activity Before MSE (Part I) (PI 1.3.1, 2.1.2, 3.2.3, 5.1.1, 5.2.2, 6.3.1, 9.1.2, 11.3.1)*	

	Each group (max 4 students) will analyze medical imaging data, process scan data, and create a 3D medical model by addressing the following aspects: *A. Compare different medical imaging modalities (CT, CBCT, MR) by evaluating their working principles, advantages, and applications in medical diagnostics.* *B. Process a given DICOM dataset, apply enhancement and segmentation techniques, and extract critical anatomical structures for 3D model generation.* *C. Utilize appropriate software tools to generate and refine a point cloud model from processed medical scan data for 3D reconstruction.* *D. Validate the accuracy of the 3D medical model by comparing it with anatomical references, ensuring precision in alignment and detail.* *E. Prepare a technical report summarizing the methodology, findings, and challenges. Present the final 3D model and analysis in a group discussion.*	
04.	**Preprocessing of Medical Scan Data for 3D Printing** ***Learning Objectives:*** *Develop skills in preprocessing scan data for 3D printing applications.*	**6-8**
	Contents: Tangible Model Creation – Methods for converting digital medical data into physical models using 3D printing and other fabrication techniques; Core Concepts of Medical Modeling – Understanding orientation, alignment, and spatial positioning of anatomical structures; Sectioning Techniques – Strategies for slicing models to enhance visualization and manufacturing feasibility; Component Separation and Assembly – Methods for dividing complex structures and reassembling them for medical applications; Managing Enclosed Spaces – Identifying and resolving trapped volumes in 3D models to ensure accuracy in printing and manufacturing.	
	Self-Learning Topics: *AI-driven 3D Model Optimization, Mesh Repair Techniques, STL File Manipulation*	
	Learning Outcomes: *A learner will be able to* *LO 4.1: Categorize different preprocessing techniques used for converting medical scan data into tangible 3D models. (PI 1.3.1)* *LO 4.2: Identify the core concepts of medical modeling, including orientation, alignment, and spatial positioning. (PI 2.1.2)* *LO 4.3: Differentiate sectioning techniques based on their effectiveness in visualization and manufacturing feasibility. (PI 3.2.3)* *LO 4.4: Analyze methods for separating and assembling complex anatomical structures for medical applications. (PI 2.3.1)* *LO 4.5: Examine strategies for detecting and resolving enclosed spaces in 3D models to ensure accuracy in printing. (PI 1.4.1)* *LO 4.6: Apply systematic techniques to improve the accuracy and reliability of medical models before 3D printing. (PI 3.3.1)*	
05.	**3D Printing and Post-Processing techniques in Bio-Modeling** ***Learning Objective/s:*** *Examine 3D printing techniques, post-processing, and integration in medical applications.*	**7-9**
	Contents:	

	Additive Manufacturing for Bio-Modeling – Overview of 3D printing technologies used to create anatomical models for medical applications; Post-Processing: Cleaning Medical Models – Methods for cleaning 3D-printed models to ensure accuracy and hygiene; Sterilization Techniques – Best practices for sterilizing medical models to prevent contamination and ensure safety in clinical settings; Integration of Additive Manufacturing in Medicine – Applications of these technologies in surgery planning, prosthetics, and personalized healthcare.	
	Self-Learning Topics: *Biocompatible Materials, Smart Prosthetics, Post-Processing Automation*	
	Learning Outcomes : *A learner will be able to* *LO 5.1: Identify different 3D printing technologies used in bio-modeling applications. (PI 1.3.1)* *LO 5.2: Compare post-processing methods for cleaning and refining 3D-printed medical models. (PI 2.1.2)* *LO 5.3: Evaluate sterilization techniques to ensure the biocompatibility of medical models. (PI 2.3.1)* *LO 5.4: Analyze the role of material properties in determining the structural integrity of 3D-printed models. (PI 1.4.1)* *LO 5.5: Apply optimization techniques to improve accuracy and efficiency in medical 3D printing workflows. (PI 2.4.3)*	
06.	**Case Studies** ***Learning Objective/s:*** *Analyze case studies in bio-modeling and assess their impact on patient-specific healthcare.*	**5-7**
	Contents: Case Studies in Bio-Modeling, Impact on Patient-Specific Healthcare, Technological Advancements in Bio-Modeling, Challenges and Solutions, Future Trends in Bio-Modeling	
	Self-Learning Topics: *Digital Twin Technology, AI in Personalized Medicine, Future of Bio-Modeling*	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Examine real-world case studies in bio-modeling and assess their impact on patient-specific healthcare solutions. (PI 1.3.1)* *LO 6.2: Categorize technological advancements in bio-modeling, including AI-driven modeling and bio printing. (PI 2.1.1)* *LO 6.3: Identify challenges in bio-modeling applications and propose feasible solutions. (PI 2.2.4)* *LO 6.4: Analyze ethical considerations and regulatory frameworks governing medical 3D printing. (PI 2.3.1, PI 9.3.1)* *LO 6.5: Evaluate the role of material properties in enhancing the reliability and accuracy of bio-models. (PI 1.4.1, PI 3.3.1)*	

	LO 6.6: Investigate emerging trends in bio-modeling and their potential applications in personalized medicine. (PI 5.2.2, PI 6.2.1) *LO 6.7: A Task-Based Group Activity After MSE (Part II) (PI 1.3.1, PI 2.1.1, PI 2.2.4, PI 2.3.1, PI 5.1.1, PI 5.2.2, PI 6.3.1, PI 9.1.2, PI 11.3.1)* *Each group (max 4 students) will evaluate a real-world medical 3D printing case study and develop a bio-modeling workflow, addressing the following:* ***Part 1: Case Study Analysis*** *A. Investigate and summarize a specific bio-modeling case study, focusing on its clinical significance and technological implementation.* *B. Analyze the technological advancements used in the case study, such as AI integration, material selection, and post-processing methods* *C. Identify challenges faced in implementing bio-modeling solutions and propose feasible engineering modifications.* *D. Discuss ethical and regulatory concerns related to bio-modeling and propose compliance strategies.* ***Part 2: Hands-On Application*** *A. Select and preprocess medical imaging data from open-source datasets and perform segmentation to extract anatomical structures.* *B. Generate a 3D printable model by optimizing geometry, refining surface details, and ensuring printability.* *C. Validate the accuracy of the 3D model using anatomical references and propose improvements.* *D. Prepare and present a technical report summarizing findings, methodologies, and conclusions.*	
	Course Conclusion Upon completion of the course, students will develop a strong foundation in medical imaging, scan data processing, and bio-modeling. By understanding and applying 3D printing technologies in healthcare, they can contribute to innovations in surgical planning, prosthetics, and personalized medicine. The integration of real-world case studies will provide insights into the challenges and advancements in medical modeling. With continuous learning and adaptation to emerging technologies, students will be well-equipped to drive future developments in medical technology and bio-modeling.	**01**
	Total	**45**

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
2.2.3	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.
2.4.3	Identify sources of error in the solution process, and limitations of the solution.
3.2.1	Apply formal idea generation tools to develop multiple engineering 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
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling and analysis; techniques and resources for engineering activities
5.2.2	Demonstrate proficiency in using discipline-specific tools
5.3.2	Verify the credibility of results from tool use with reference to the accuracy and limitations, and the assumptions inherent in their use.
6.2.1	Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public
6.3.1	Identify risks/impacts in the life-cycle of an engineering product or activity
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. Apply fundamental concepts of medical technology and modeling workflows. (*LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5, LO 1.6*)
2. Analyze various medical imaging techniques for data capturing of 3D Modeling. (*LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 2.6)*
3. Perform medical scan data processing and optimization for 3D modeling. (*LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5, LO 3.6, LO 3.7, LO 3.8)*
4. Analyze pre-processing techniques to enhance 3D printing accuracy. (*LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 4.6)*
5. Demonstrate post-processing and sterilization techniques for medical 3D models. (*LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 5.5)*
6. Apply & analyse various aspects of data capturing of medical imaging techniques through case studies. (*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
HMCAM602.1	3	3	--	--	--	--	--	--	--	--	--
HMCAM602.2	3	3	--	--	--	--	--	--	--	--	--
HMCAM602.3	3	3	3	--	3	3	--	--	3	--	2
HMCAM602.4	3	3	3	--	--	--	--	--	--	--	--
HMCAM602.5	3	3	--	--	--	--	--	--	--	--	--
HMCAM602.6	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. Raja, M., & Fernandes, P. (2021). Medical Imaging and 3D Modeling in Healthcare. CRC Press.
2. Suetens, P. (2017). Fundamentals of Medical Imaging (2nd Edition). Cambridge University Press.
3. Durrani, S. K., & Singh, H. (2020). Biomedical Imaging and Image Processing Techniques. McGraw Hill India.

Reference Books :

1. Webb, S. (2019). The Physics of Medical Imaging.
2. Joshi, P., & Naik, R. (2021). 3D Printing in Biomedical Engineering.

Other Resources :

1. NPTEL Course: Medical Image Analysis
   Web link: https://nptel.ac.in/courses/102/106/102106051/

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment - Theory-(20 Marks)

Suggested breakup of distribution

A task based group activity, before MSE. (Part I)	:	05 Marks
A task based group activity, after MSE. (Part II)	:	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.

Syllabi
Third Year
Supply Chain

Course Type	Course Code	Course Name	Credits
HMC	HMCSC501	FUNDAMENTALS OF LOGISTICS MANAGEMENT	03

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: Nil

Program Outcomes addressed:

1. PO2: Problem analysis
2. PO3: Design/development of solutions
3. PO6: The engineer and the world
4. PO10: Project management and finance
5. PO11: Life-long learning

Course Objectives:

1. To familiarize the role of logistics management in business operations.
2. To acquaint with transportation modes and their suitability for different types of goods.
3. To inculcate principles of warehousing and distribution.
4. To familiarize the methods for designing and optimizing supply chains.

Module	Details	Hrs.
	Course Introduction This course is intended to provide a thorough understanding of the fundamental principles, concepts, and methods involved in logistics management. This course will cover a variety of logistics management topics, including as transportation, inventory management, warehousing, distribution, and logistics technologies. It will be discussed at how these components interact within the larger supply chain ecosystem and discuss ways for optimizing logistics procedures to increase efficiency, lower costs, and improve customer satisfaction. By the end of this course, the student will have a firm foundation in logistics management principles and will be equipped to face the challenges of efficiently managing logistics operations.	**01**
01.	**Introduction to Logistics Management** ***Learning Objective:*** *To gain the knowledge of fundamentals of logistics management in current corporate operations, to improve efficiency, reduce costs, and increase customer satisfaction.*	**06**

	Contents: Definition and importance of logistics management, Evolution of logistics management concepts, Objectives and scope of logistics management Logistics Strategy and Planning - Formulating logistics strategies, Aligning logistics strategy with business strategy, Role of logistics in achieving competitive advantage	
	Learning Outcomes: *A learner will be able to* *LO1.1: Inculcate logistics management's essential concepts and principles, as well as its position in the larger context of supply chain management. (P.I.- 2.1.1)* *LO1.2: Use logistic management strategies to identify and address typical difficulties and inefficiencies in logistics operations, recommending solutions to improve efficiency and effectiveness. (P.I.- 2.1.3, P.I.- 3.1.6)* *LO1.3: Recognize logistics management's strategic importance in gaining a competitive advantage and supporting organizational goals, as well as its function in improving customer satisfaction and market responsiveness. (P.I.- 3.1.1, P.I.- 10.2.1, P.I.- 10.3.1)*	
02.	**Transportation Management** ***Learning Objective:*** *To familiarize the transportation management principles and techniques, to efficiently manage transportation operations, reduce costs, mitigate risks, and contribute to the overall success of organizations' logistics functions.*	**09**
	Contents: Modes of transportation, Transportation planning and routing, Freight rates and carrier selection, Containerization, Distribution management Assignment problem, Transportation problem	
	Learning Outcomes: *A learner will be able to* *LO2.1: Identify various transportation modes such as road, rail, air, sea, and inter-modal, including their advantages, limitations, and suitability for different types of cargo and distances. (P.I.- 2.1.1, P.I.- 2.2.2, P.I.- 2.2.4)* *LO2.2: Analyze coordination of logistics activities such as scheduling, routing, tracking, and monitoring transportation activities to ensure timely delivery while optimizing costs. (P.I.- 10.3.2)* *LO2.3: Illustrate the role of transportation management within the broader supply chain and the importance of integration with procurement, production, inventory management, and distribution. (P.I.- 10.3.1)*	
03.	**Warehousing and Inventory Management** ***Learning Objective:*** *To acquaint with warehouse operations, warehouse layout and design, and inventory control techniques along with the material handling equipment.*	**10**
	Contents: Warehouse operations and layout design, Inventory control methods (e.g., EOQ, ABC, XYZ, VED, SDE, HML, FSN, SOS, GOLF analysis)	

	Cycle counting and inventory accuracy, Cross docking, material handling equipment (MHE)	
	Learning Outcomes: *A learner will be able to* *LO3.1: Design and manage warehouse layouts to maximize space utilization, minimize travel time, and streamline material flow for efficient operations. (P.I.- 3.1.1, P.I.- 3.1.6)* *LO3.2: Utilize inventory optimization models and strategies, including ABC analysis, EOQ, safety stock, and reorder point, to ensure the right balance between inventory investment and service level. (P.I.- 2.1.1)* *LO3.3: Manage inventory levels to meet demand while minimizing holding costs, stockouts, and excess inventory. (P.I.- 10.1.1)*	
04.	**Distribution Channels** ***Learning Objectives:*** *To impart knowledge and skills about the design, management, and optimization of channels that transport goods or services from producers to customers.*	**06**
	Contents: Types of distribution channels (e.g., direct, indirect), Role of wholesalers and retailers, Order fulfillment processes and service levels Logistics Information Systems - Role of information technology in logistics management, Warehouse Management Systems (WMS), Supply chain visibility and tracking technologies	
	Learning Outcomes: *A learner will be able to* *LO4.1: Identify different types of distribution channels and explain their characteristics, advantages, and limitations. (P.I.- 2.1.2)* *LO4.2: Optimize distribution channels to maximize market coverage, minimize costs, and enhance customer satisfaction. (P.I.- 10.1.1)* *LO4.3: Develop the ability to adapt distribution channel strategies to changing market conditions, technological advancements, and consumer preferences. (P.I.- 11.1.1, P.I.- 11.2.2)*	
05.	**Packaging and Materials Handling** ***Learning Objective/s:*** *To impart knowledge and skills related to the design, selection, and management of packaging solutions and equipment used in handling materials within various industries.*	**06**
	Contents: Importance of packaging in logistics, Types of packaging materials and designs, Materials handling equipment and techniques	
	Learning Outcomes : *A learner will be able to* *LO5.1: Analyze packaging requirements and design appropriate packaging solutions considering factors such as product protection, transportation, and consumer appeal. (P.I.- 2.1.1, P.I.- 6.1.2)* *LO5.2: Identify different packaging materials, their properties, and suitability for various products and applications. (P.I.- 2.2.2, P.I.- 6.2.1)*	

	LO5.3: Identify and select appropriate type of material handling equipment, including conveyors, forklifts, and automated systems. (P.I.- 2.1.2)	
06.	**Reverse Logistics and Sustainability** ***Learning Objective/s:*** *To acquaint with principles, practices, and challenges associated with managing product returns, recycling, and sustainable supply chain operations* **Contents:** Reverse logistics processes (e.g., returns management, recycling), Sustainable logistics practices, Environmental impact reduction strategies International Logistics - Key considerations in international logistics, Customs regulations and documentation, Incoterms and international trade terms Emerging Trends in Logistics - E-commerce and omnichannel logistics, Last-mile delivery innovations, Future challenges and opportunities in logistics management A case study on 'Reverse Logistics and Sustainability', with a focus on reducing waste, reusing materials, and recycling ***Learning Outcomes:*** *A learner will be able to* *LO6.1: Explain the key components and processes involved in reverse logistics, such as product returns management, refurbishment, and recycling. (P.I.- 2.1.2, P.I.- 2.2.2)* *LO6.2: Incorporate environmental and social considerations into reverse logistics planning and execution. (P.I.- 6.1.2)* *LO6.3: Illustrate emerging trends and technologies in reverse logistics to enhance its efficiency, transparency, and sustainability. (P.I.- 6.2.1)*	**06**
	Course Conclusion	**01**
	Total	**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
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.
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.
3.1.6	Determine design objectives, functional requirements and arrive at specifications.
6.1.2	Understand the relationship between the technical, socio-economic and environmental dimensions of sustainability.
6.2.1	Describe management techniques for sustainable development.
10.1.1	Describe various economic and financial costs/benefits of an engineering activity.
10.2.1	Analyse 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 complete the tasks.
10.3.2	Use project management tools to schedule an engineering project, so it is completed on time and on budget.
11.1.1	Describe the rationale for the requirement for continuing professional development.

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: A learner will be able to -

1. Interpret the core concepts, principles, and terminology related to logistics management. (*LO1.1, LO1.2, LO1.3*)
2. Apply the knowledge of key logistics functions, including transportation, warehousing, inventory management, distribution channels and supply chain coordination. (*LO2.1, LO2.2, LO2.3, LO3.1, LO3.2, LO3.3, LO4.1, LO4.2, LO4.3*)
3. Illustrate packaging and material handling systems to identify inefficiencies, bottlenecks, and opportunities for improvement. (*LO5.1, LO5.2, LO5.3*)
4. Apply the knowledge of sustainability principles and their application in supply chain management, including environmental, social, and economic considerations. (*LO6.1, LO6.2*)
5. Illustrate awareness of emerging trends and challenges in global logistics. (*LO6.3*)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCSC501.1	--	3	3	--	--	--	--	--	--	3	--
HMCSC501.2	--	3	3	--	--	--	--	--	--	3	3
HMCSC501.3	--	3	--	--	--	3	--	--	--	--	--
HMCSC501.4	--	3	--	--	--	3	--	--	--	--	--
HMCSC501.5	--	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. "Introduction to Logistics Systems Management" by Gianpaolo Ghiani, Gilbert Laporte, and Roberto Musmanno, 2nd Edition, John Wiley & Sons Inc.

Reference Books :

1. "Logistics & Supply Chain Management" by Martin Christopher, 6th Edition, Pearson Education Limited.
2. "Supply Chain Logistics Management" by Donald J. Bowersox, David J. Closs, and M. Bixby Cooper, 3rd Edition, McGraw-Hill Education / Asia.
3. "Supply Chain Management: Strategy, Planning, and Operation" by Sunil Chopra and Peter Meindl, 6th Edition, Pearson.

Other Resources :

1. NPTEL Course: ‘Operations and Supply Chain Management’ By Prof. G. Srinivasan, Department of Management Studies, IIT Madras.
   Web link- https://www.nptelvideos.com/course.php?id=681
2. NPTEL Course: ‘Modelling and Analytics for Supply Chain Management’ By Prof. Kunal Kanti Ghosh, Prof. Anupam Ghosh, IIT Kharagpur
   Web link- https://onlinecourses.nptel.ac.in/noc25_mg48/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 carrying 20% weightage, and the syllabus covered from MSE to ESE carrying 80% weightage

Course Type	Course Code	Course Name	Credits
HMC	HMCSC602	OPERATIONS AND SUPPLY CHAIN MANAGEMENT	03

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: Fundamentals of Logistics Management

Program Outcomes addressed:

1. PO 2: Problem analysis
2. PO 3: Design/development of solutions
3. PO 6: The engineer and the world
4. PO 7: Ethics
5. PO 10: Project management and finance
6. PO 11: Life-long learning

Course Objectives :

1. To comprehend the role and significance of supply chain management in business operations.
2. To acquaint with the techniques of demand forecasting and inventory management to balance costs and service levels.
3. To familiarize the ethical implications of supply chain decisions and develop strategies to promote ethical behaviour.
4. To know the role of emerging information technologies in operations and supply chain management.

Module	Details	Hrs
	Course Introduction The course, Operations and Supply Chain Management, is intended to give students a full understanding of the principles, strategies, and practices that underpin the essential business functions. The subject delves into the interrelated processes that go into creating things and providing services, from raw material procurement to final customer delivery. Students will learn how to design, manage, and optimise these processes in order to achieve operational excellence and create a competitive edge.	01
01.	**Introduction to Supply Chain Management**	06

	Learning Objective: *To gain the knowledge of fundamentals of supply chain management in current corporate operations, and to explore different supply chain strategies and their alignment with business strategies.*	
	Contents:	
	Definition and importance of supply chain management, Evolution of supply chain management concepts, Objectives and benefits of effective supply chain management Supply Chain Strategy - Formulating supply chain strategies, Aligning supply chain strategy with business strategy, Competitive advantage through supply chain management, Supply chain integration and Bullwhip effect	
	Learning Outcomes : *A learner will be able to* *LO1.1: Identify the various components and functions of a supply chain and understand how they interrelate. (P.I.- 2.1.1, P.I.- 2.2.2, P.I.- 10.2.1)* *LO1.2: Analyze different supply chain structures and strategies, and understand their implications for business performance. (P.I.- 2.1.3, P.I.- 2.2.4, P.I.- 10.3.1)*	
02.	**Demand Forecasting and Planning**	**08**
	Learning Objective: *To familiarize with integration of demand forecasting with planning processes such as sales and operations planning and explore how forecasts are used to drive decision-making in procurement, production, and distribution.*	
	Contents: Forecasting methods, techniques and their limitations in the context of its application in diverse business situations, Sales and operations planning (S&OP), Demand-driven supply chains	
	Learning Outcomes : *A learner will be able to* *LO2.1: Identify and apply appropriate forecasting techniques based on specific business contexts and data availability. (P.I.- 2.1.3, P.I.- 2.4.1, P.I.- 10.2.1)* *LO2.2: Measure and improve forecast accuracy using standard error metrics. (P.I.- 2.4.3, P.I.- 3.4.2)* *LO2.3: Integrate demand forecasts into broader planning processes to enhance decision-making. (P.I.- 3.3.1)*	
03.	**Inventory Management**	**10**
	Learning Objective: *To acquaint with the importance of inventory management in the overall supply chain and its impact on business performance.*	
	Contents: Inventory types and classifications, Inventory management in the context of supply chain optimization, customer satisfaction and demand fulfilment, cost control and profitability, JIT, seasonal and promotional inventory planning Inventory control models (e.g., EOQ, ABC analysis), Multi-echelon inventory optimization Case study on one of the EOQ model	
	Learning Outcomes :	

	A learner will be able to *LO3.1: Apply various inventory management strategies and control techniques to maintain optimal inventory levels. (P.I.- 2.2.4, P.I.- 2.4.1)* *LO3.2: Analyze costs associated with inventory and develop strategies to balance these costs effectively. (P.I.- 3.1.6, P.I.- 10.3.2)*	
04.	**Supplier Relationship Management** ***Learning Objective:*** *To acquaint with the fundamental concepts and principles of SRM and learn about procurement strategies that align with overall business goals.* **Contents:** Sourcing strategies and supplier selection criteria, Supplier performance measurement and evaluation. Collaborative supplier relationships Procurement and Contract Management - Procurement process and procedures, Contract negotiation and management, Risk management in procurement ***Learning Outcomes :*** *A learner will be able to* *LO4.1: Illustrate a thorough understanding of the core principles and concepts of SRM. (P.I.- 2.1.1, P.I.- 2.1.3)* *LO4.2: Apply techniques to segment and categorize suppliers based on their strategic importance and value to the organization. (P.I.- 2.2.4, P.I.- 3.2.1, P.I.- 3.2.3)* *LO4.3: Align sourcing and procurement strategies with overall business objectives to achieve better outcomes. (P.I.- 10.2.1, P.I.- 10.3.1)*	**07**
05.	**Supply Chain Risk Management** ***Learning Objective:*** *To recognize different types of risks that can impact the supply chain and understand the importance of SCRM in ensuring supply chain resilience and continuity.* **Contents:** Identifying and assessing supply chain risks, Mitigation strategies and contingency planning, Resilience and agility in supply chain operations ***Learning Outcomes :*** *A learner will be able to* *LO5.1: Identify and categorize various supply chain risks. (P.I.- 2.2.2, P.I.- 6.1.1)* *LO5.2: Develop and implement effective risk mitigation strategies and controls. (P.I.- 2.2.4, P.I.- 3.2.3, P.I.- 6.2.1)* *LO5.3: Implement strategies to build a more resilient and agile supply chain. (P.I.- 2.1.2, P.I.- 3.3.1)*	**06**
06.	**Information Technology in Supply Chain Management** ***Learning Objective:*** *To acquaint with fundamental concepts and importance of IT in enhancing supply chain operations and explore how IT can support sustainable and ethical supply chain practices..* **Contents:** Role of information technology in SCM, Supply chain visibility and transparency, Enterprise Resource Planning (ERP) systems Sustainability and Ethical Considerations in SCM - Sustainable supply chain practices, Ethical sourcing and corporate social responsibility, Green logistics and environmental impact reduction ***Learning Outcomes :***	**06**

	A learner will be able to *LO6.1: Demonstrate a deep understanding of the role and importance of IT in enhancing supply chain operations. (P.I.- 2.1.2, P.I.- 11.2.1, P.I.- 11.2.2, P.I.- 11.3.2)* *LO6.2: Identify, assess, and mitigate supply chain risks using IT solutions. (P.I.- 2.2.4, P.I.- 6.1.1, P.I.- 6.2.1, P.I.- 6.3.1, P.I.- 6.4.2, P.I.- 7.1.1, P.I.- 7.2.2)*	
	Course Conclusion	**01**
	Total	**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
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.
2.2.4	Compare and contrast alternative solution processes to select the best 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.
3.1.6	Determine design objectives, functional requirements and arrive at specifications.
3.2.1	Apply formal idea generation tools to develop multiple engineering design solutions.
3.2.3	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.
3.4.2	Generate information through appropriate tests to improve or revise the design.
6.1.1	Identify and describe various engineering roles; particularly as pertains to protection of the public and public interest at the global, regional and local level.
6.2.1	Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public.
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
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.
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 complete the tasks.
10.3.2	Use project management tools to schedule an engineering project, so it is completed on time and on budget.
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. Interpret the core concepts, principles, and terminology in operations and supply chain management and articulate its strategies with overall business goals. (*LO1.1, LO1.2*)
2. Apply demand forecasting techniques to anticipate market needs and use inventory control models to balance supply and demand effectively. (*LO2.1, LO2.2, LO2.3, LO3.1, LO3.2*)
3. Apply principles of supplier relationship management to enhance supply chain performance. (*LO4.1, LO4.2, LO4.3*)

4. Identify potential risks within the supply chain and develop strategies to mitigate these risks. (*LO5.1, LO5.2, LO5.3*)
5. Illustrate the impact of emerging technologies in IT systems to improve supply chain operations. (*LO6.1, LO6.2*)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCSC602.1	--	3	--	--	--	--	--	--	--	3	--
HMCSC602.2	--	3	3	--	--	--	--	--	--	3	--
HMCSC602.3	--	3	3	--	--	--	--	--	--	3	--
HMCSC602.4	--	3	3	--	--	3	--	--	--	--	--
HMCSC602.5	--	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. "Operations and Supply Chain Management" by F. Robert Jacobs, Richard B. Chase and Ravi Shankar, 17th Edition, McGraw Hill.
2. "Supply Chain Management: Strategy, Planning, and Operation" by Sunil Chopra and Peter Meindl, 6th Edition, Pearson.

Reference Books :

1. "Introduction to Operations and Supply Chain Management" by Cecil B. Bozarth and Robert B. Handfield, 4th Edition, Pearson.
2. "Logistics and Supply Chain Management" by Martin Christopher, 5th Edition, FT Publishing International.
3. "Operations Management: Processes and Supply Chains" by Lee J. Krajewski, Manoj K. Malhotra, and Larry P. Ritzman, 11th Edition, Pearson.

Other Resources :

1. NPTEL Course: 'Operations and Supply Chain Management' By Prof. G. Srinivasan, Department of Management Studies, IIT Madras.
   Web link- https://www.nptelvideos.com/course.php?id=681
2. NPTEL Course: 'Modelling and Analytics for Supply Chain Management' By Prof. Kunal Kanti Ghosh, Prof. Anupam Ghosh, IIT Kharagpur
   Web link- https://onlinecourses.nptel.ac.in/noc25_mg48/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 carrying 20% weightage, and the syllabus covered from MSE to ESE carrying 80% weightage

Syllabi

Third Year

Aeronautical Engineering

Course Type	Course Code	Course Name	Credits
HMC	HMCAN501	BASICS OF AERONAUTICAL ENGINEERING	03

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

Pre-requisite :

1. ESC101 : Engineering Mechanics
2. MEPCC302 : Mechanics of Solids
3. MEPCC304 : Thermodynamics
4. MEPCC407 : Thermal 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. PO5: Engineering Tool Usage
6. PO8: Individual and Collaborative Team Work
7. PO9: Communication
8. PO11: Life-Long Learning

Course Objectives :

1. Introduce students to various airplane configurations, aerodynamic forces, and key flight parameters.
2. Guide students in analysing aircraft motion, stability, and performance metrics, including range and endurance.
3. Provide a deep understanding of aerospace structures, materials, and the principles behind their selection.
4. Familiarize students to the fundamentals of gas turbine engines and the principles of thrust generation.
5. Instruct students on the aerodynamics and performance factors related to propellers and compressors.
6. Explore turbine design, efficiency considerations, and advanced cooling technologies.

<table>
<tr><th>Module</th><th>Details</th><th>Hrs</th></tr>
<tr><td></td><td>This aerospace course provides students with essential knowledge in aerodynamics, aircraft performance, propulsion systems, and more, serving as a foundational course for advanced studies. It covers both theoretical concepts and practical applications, making students well-prepared for further specialized courses. It equips them with the basic knowledge required for pursuing advanced courses in the domain. The course also provides enough information required for basic modelling of multi copter and fixed wing drones.</td><td>01</td></tr>
<tr><td>01.</td><td>Basic Aerodynamics
Learning Objective/s:
1. To identify airplane configurations, components, and their functions, and analyze the role of the standard atmosphere in flight performance.
2. To examine aerodynamic forces and moments, and study airfoil and wing aerodynamics, including parameters like airspeed, Mach number, Reynolds number, and drag polar.</td><td>5-7</td></tr>
<tr><td></td><td>Contents:
Airplane configurations, components of airplane, functions, Standard Atmosphere, Aerodynamic forces and Moments, Air speed, Mach Number, Reynold’s Number, Airfoil Aerodynamics, Wing Aerodynamics and Drag Polar.</td><td></td></tr>
<tr><td></td><td>Self-Learning Topics:
Importance and applications of Drag Polar.

Learning Outcomes :
A learner will be able to
LO 1.1 Identify airplane configurations, components, and their functions in flight. (PI 1.3.1, PI 2.1.2)
LO 1.2 Analyze the role of the standard atmosphere on aircraft performance. (PI 1.1.2, PI 2.3.1)
LO 1.3 Examine aerodynamic forces, moments, and key parameters like airspeed, Mach number, and Reynolds number. (PI 2.1.2, PI 2.3.1)
LO 1.4 Evaluate airfoil and wing aerodynamics, including drag polar curves and aerodynamic efficiency. (PI 1.2.1, PI 2.3.1, PI 4.3.4, PI 8.1.2, PI 9.1.2)</td><td></td></tr>
<tr><td>02.</td><td>Aircraft Performance, Stability & Control
Learning Objective/s:
1. To comprehend coordinate systems, equations of motion, and degrees of freedom, and analyze pitch, roll, and yaw.
2. To compute performance parameters like climb rate, ceiling, range, endurance, glide, and descent, and understand stability and control principles.</td><td>6-8</td></tr>
<tr><td></td><td>Contents:
Coordinate systems, Equations of motion, degrees of freedom, pitch, roll, yaw, introduction to performance parameters: rate of climb, absolute & service ceiling, Range, maximum endurance, glide, descent, Principles of stability and control.</td><td></td></tr>
</table>

	Self-Learning Topics: *Glide and descent*	
	Learning Outcomes : *A learner will be able to* *LO 2.1 Identify coordinate systems, equations of motion, and degrees of freedom, and apply them in flight dynamics. (PI 1.2.1, PI 2.3.1, PI 4.3.4)* *LO 2.2 Analyze the effects of pitch, roll, and yaw on aircraft stability and control. (PI 1.2.1, PI 2.3.1, PI 4.3.4)* *LO 2.3 Calculate and interpret key performance parameters, including rate of climb, ceiling, range, endurance, glide, and descent. (PI 2.4.1, PI 4.3.4)* *LO 2.4 Evaluate the principles of aircraft stability and control and their impact on flight behavior. (PI 2.4.1, PI 4.3.4, PI 5.2.2, PI 8.1.2, PI 9.1.2)*	
03.	**Basics of Aircraft Structures** ***Learning Objective/s:*** 1. *Evaluate stress, strain, and stress-strain diagrams, and compare monocoque and semi-monocoque designs in aircraft.* 2. *Classify aircraft materials, assess strength/weight ratio, and explore rivets, welding methods, and stealth materials.*	**5-7**
	Contents: Stress, strain, stress-strain diagram for elastic materials, Monocoque and semi-monocoque structures – Wing, fuselage, types of rivets and welding methods – Materials used in aircraft – Classification of aircraft materials - Importance of strength/weight ratio of materials for aerospace vehicles structures, Materials used for aircraft components - Factors affecting choice of material for different parts of airplane. Materials for stealth - Emerging trends in aerospace materials.	
	Self-Learning Topics: *Emerging trends in aerospace materials.*	
	Learning Outcomes : *A learner will be able to* *LO 3.1 Analyze stress, strain, and stress-strain diagram in aircraft structures.* *(PI 1.2.1, PI 2.4.1, PI 4.3.4)* *LO 3.2 Differentiate between monocoque and semi-monocoque structures and their applications. (PI 1.3.1, PI 2.1.2, PI 3.2.3)* *LO 3.3 Classify aircraft materials and evaluate their strength/weight ratio and suitability. (PI 1.4.1, PI 2.1.2, PI 4.3.4)* *LO 3.4 Assess factors affecting material selection, including those for stealth technology and emerging trends. (PI 2.1.2, PI 4.3.4, PI 8.1.2, PI 9.1.2, PI 11.2.2)*	

04.	**Basics of Aircraft propulsion** ***Learning Objective/s:*** *1. Analyze engine operation, thrust generation, and factors affecting performance.* *2. Compare turboprop, turbofan, turbojet, and turboshaft engines, and assess Brayton cycles and thrust augmentation methods.*	**7-9**
	Contents: Working of Gas turbine engines –the thrust equation and other performance parameters– Factors affecting thrust –Variants of Aircraft jet engines: Turboprop, Turbofan, Turbojet and Turboshaft - Performance characteristics and analysis, Ideal and Real Brayton cycles - analysis, Methods of thrust Augmentation.	
	Self-Learning Topics: *Methods of thrust Augmentation.*	
	Learning Outcomes : *A learner will be able to* *LO 4.1 Outline the working principles of gas turbine engines and thrust generation. (PI 1.2.1, PI 2.1.2)* *LO 4.2 Identify factors affecting thrust in aircraft engines. (PI 1.2.1, PI 2.1.2)* *LO 4.3 Compare the performance of turboprop, turbofan, turbojet, and turboshaft engines. (PI 2.1.2)* *LO 4.4 Analyze Brayton cycles and methods of thrust augmentation. (PI 2.3.1)*	
05.	**Propeller Theory and Compressors** ***Learning Objective/s:*** *1. Analyze propeller aerodynamics and the operation of centrifugal and axial compressors, including surging, choking, and velocity diagrams.* *2. Analyze compressor design and performance: Examine key design parameters and performance characteristics in centrifugal and axial compressors.*	**7-9**
	Contents: **Propeller Fundamentals** - propeller aerodynamic theories – momentum, blade elemental and vortex theory, Introduction to helicopter, Drone and marine propellers. **Centrifugal Compressors** - Principle of operation – work done and pressure rise- slip factor, velocity diagrams, diffuser vane design considerations, Concept of Surging, choking, pre-whirl, rotating stall, Performance characteristics. **Axial Compressors** - Elementary theory – Velocity triangles – Work and compression, Design parameters - Degree of reaction - diffusion factor. Single and multi-stage axial compressor performance characteristics.	
	Self-Learning Topics: *Drone and marine propellers, compressor performance characteristics*	
	Learning Outcomes : *A learner will be able to* *LO 5.1 Analyze propeller aerodynamics, including momentum, blade elemental, and vortex theory, and apply them to helicopter, drone, and marine propellers. (PI*	

	1.2.1, PI 2.3.1, PI 2.4.1) *LO 5.2 Identify the principles of centrifugal compressors, including work, pressure rise, slip factor, velocity diagrams, surging, choking, and rotating stall. (PI 1.2.1, PI 2.1.2)* *LO 5.3 Evaluate the performance of centrifugal compressors, focusing on diffuser vane design and operational characteristics. (PI 2.4.1, PI 2.3.1)* *LO 5.4 Apply axial compressor theory, including velocity triangles, work, compression, degree of reaction, and diffusion factor, to assess performance in single and multi-stage designs. (PI 2.3.1, PI 2.4.1)*	
06.	**Axial and Radial Turbines**	**7-9**
	Learning Objective/s: *1. Analyze vortex theory, blade profile, work done, degree of reaction, performance, and stresses.* *2. Assess multi-stage turbines, cooling technology, and losses/efficiency in radial turbines..*	
	Contents: **Axial Turbines** - Elementary theory – vortex theory – choice of blade profile, pitch and chord, Work done - degree of reaction, Losses, efficiency and performance, Rotor blade and disc stresses, Multi-staging of turbine, Turbine cooling technology **Radial flow turbines:** Radial turbine - Aerodynamics and thermodynamics, Losses in radial turbine and efficiency.	
	Self-Learning Topics: *Turbine cooling technology, Losses in radial turbine* ***Learning Outcomes :*** *A learner will be able to* *LO 6.1 Outline the principles of axial turbines, including vortex theory, blade profile selection, and performance factors like efficiency, losses, and rotor blade stresses. (PI 1.2.1, PI 2.3.1, PI 4.3.4)* *LO 6.2 Analyze multi-stage turbine design and cooling technologies for improved performance. ((PI 2.3.1, PI 2.4.1, PI 4.3.4)* *LO 6.3 Evaluate the aerodynamics and thermodynamics of radial turbines, including losses and efficiency. (PI 1.2.1, PI 2.4., PI 4.3.4)*	
	Course Conclusion	**01**
Total		**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
PI 1.1.2	Apply advanced mathematical techniques to model and solve mechanical engineering problems.
PI 1.2.1	Apply laws of natural science to an engineering problem.
PI 1.3.1	Apply fundamental engineering concepts to solve engineering problems.
PI 1.4.1	Apply Mechanical Engineering concepts to solve engineering problems.
PI 2.1.2	Identify engineering systems, variables, and parameters to solve problems.

PI 2.3.1 Combine scientific principles and engineering concepts to formulate model(s) of a system or process that is appropriate in terms of applicability and required accuracy.

PI 2.4.1 Apply engineering mathematics and computations to solve mathematical models.

PI 3.2.3 Identify suitable criteria for the evaluation of alternate design solutions.

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

PI 5.2.2 Demonstrate proficiency in using discipline-specific tools

PI 8.1.2 Demonstrate effective team operations and communication skills.

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

PI 11.2.2 Recognize the need and clearly explain why it is vital to keep current regarding new developments in your field.

Course Outcomes : Learner will be able to

1. Analyze fundamental aerodynamic principles, airplane configurations, and their impact on overall flight performance. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4)*
2. Analyze flight dynamics and assess the effects of pitch, roll, yaw, and performance parameters on aircraft stability and control. *(LO 2.1, LO 2.2, LO 2.3, LO 2.4)*
3. Evaluate aircraft structural behavior and material selection by analyzing stress–strain relationships, differentiating structural types, and assessing material properties and suitability. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4)*
4. Assess the working principles and performance of conventional propulsion systems, including gas turbine engines and thrust generation. *(LO 4.1, LO 4.2, LO 4.3, LO 4.4)*
5. Analyze the aerodynamic and thermodynamic performance of advanced propulsion components. *(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
HMCAN501.1	3	3	--	2	--	--	--	2	2	--	--
HMCAN501.2	2	3	--	2	2	--	--	2	2	--	--
HMCAN501.3	3	3	2	2	--	--	--	2	2	--	2
HMCAN501.4	2	3	--	--	--	--	--	--	--	--	--
HMCAN501.5	3	3	--	2	--	--	--	--	--	--	--
Average	**3**	**3**	**2**	**2**	**2**	--	--	**2**	**2**	--	**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. J. D. Anderson, Jr., *Aircraft Performance and Design*. New York, NY, USA: McGraw Hill Education, 1st ed., 1999.
2. J. D. Anderson, Jr., *Introduction to Flight*. New York, NY, USA: McGraw Hill Education, 9th ed., 2021.

3. J. D. Anderson, Jr., *Fundamentals of Aerodynamics*. New York, NY, USA: McGraw Hill Education, 6th ed., 2016.
4. T. H. G. Megson, *Aircraft Structures for Engineering Students*. Oxford, UK: Butterworth-Heinemann (Elsevier), 6th ed., 2016.
5. T. H. G. Megson, *Introduction to Aircraft Structural Analysis*. Oxford, UK: Butterworth-Heinemann (Elsevier), 3rd ed., 2017.
6. S. Farokhi, *Aircraft Propulsion*. Hoboken, NJ, USA: Wiley, 2nd ed., 2014.
7. R. C. Nelson, *Flight Stability and Automatic Control*. New York, NY, USA: McGraw Hill Education, 2nd ed., 1998.

Reference Books :

1. J. J. Bertin and R. M. Cummings, *Aerodynamics for Engineers*. Boston, MA, USA: Pearson Education, 6th ed., 2013.
2. A. C. Kermode, Mechanics of Flight. Harlow, UK: Pearson Education, 11th ed., 2012.
3. P. G. Hill and C. R. Peterson, *Mechanics and Thermodynamics of Propulsion*. Upper Saddle River, NJ, USA: Pearson Education, 2nd ed., 1992.
4. F. S. Schaufele, *Propeller Aerodynamics*. Tabernash, CO, USA: Aircraft Technical Book Company, revised ed., 1998.
5. R. I. Lewis, *Turbomachinery Performance Analysis*. Oxford, UK: Butterworth-Heinemann (Elsevier), 1st ed., 1996.
6. V. Ganesan, *Gas Turbines*. New York, NY, USA: McGraw Hill Education, 4th ed., 2010.
7. R. S. R. Gorla and A. A. Khan, *Turbomachinery: Design and Theory*. Boca Raton, FL, USA: CRC Press, 1st ed., 2003.

Other Resources :

1. K. Ghosh, Aircraft Design. IIT Kanpur, NPTEL, 2022.
   Available: https://archive.nptel.ac.in/noc/courses/noc22/SEM1/noc22-ae01/
2. P. Kumar and B. G. Sheeja, Introduction to Airplane Performance. IIT Kanpur, NPTEL, 2015.
   Available: https://archive.nptel.ac.in/content/syllabus_pdf/101104061.pdf.
3. V. Sundararajan, Aircraft Structures. IIT Madras, NPTEL, 2015.
   Available: https://archive.nptel.ac.in/content/syllabus_pdf/101106044.pdf.
4. S. R. Chakravarthy, Aircraft Propulsion. IIT Madras, NPTEL, 2014.
   Available: https://archive.nptel.ac.in/content/syllabus_pdf/101106041.pdf.
5. R. K. Jaiswal, Compressors and Turbines. IIT Kharagpur, NPTEL, 2021.
   Available: https://archive.nptel.ac.in/content/syllabus_pdf/112104117.pdf.

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

Numerical Assignments (min 20 problems)	:	05 Marks
Class test	:	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%** 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
HMC	HMCAN602	LOW SPEED AERODYNAMICS AND FLIGHT DYNAMICS	03

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. MEPCC510 : Fluid Mechanics and Machinery
3. HMCAN501 : Basics of Aeronautical Engineering

Program Outcomes addressed :

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO4: Conduct Investigations of Complex Problems
4. PO8: Individual and Collaborative Team Work
5. PO9: Communication

Course Objectives :

1. Equip students with the knowledge of continuity, momentum, Bernoulli's equations, and flow analysis over ducts and cylinders.
2. Familiarize students to airfoil characteristics, Kutta-Joukowski transformation, and thin airfoil and finite wing theories for evaluating lift and drag.
3. Instruct students on analysing forces, drag characteristics, and performance metrics such as range, endurance, climb, and turning.
4. Educate students on static and dynamic longitudinal stability, center of gravity effects, and stick-fixed and stick-free conditions.
5. Guide students through the analysis of dihedral effects, rolling-yaw coupling, and rudder requirements for stable flight.
6. Provide insights into modes like spiral divergence, Dutch roll, autorotation, and spin, and their impact on aircraft behaviour.

Module	Details	Hrs
	Course Introduction This course, Aerodynamics and Aircraft Stability, is essential for students interested in aerospace engineering. It covers key topics like fluid dynamics, wing theory, aircraft performance, and stability analysis. Students learn about air flow, how wings generate lift, drag, power requirements, and flight	**01**

	characteristics. The course also explores how to maintain aircraft stability and control during flight. By the end, students will be equipped with the knowledge needed for advanced studies or professional work in aerospace engineering.	
01.	**Fundamentals of Inviscid Incompressible Flow** ***Learning Objective/s:*** *1. To use continuity, momentum, and Bernoulli's equations to analyze incompressible flow and irrotational flow.* *2. To examine flow over circular cylinders, including the Magnus effect and the Kutta-Joukowski theorem.*	**6-8**
	Contents: Continuity, momentum and Bernoulli's equation, incompressible flow in a duct, Pitot tube, pressure coefficient, governing equation for irrotational incompressible flow, Concept of Vorticity and circulation, Flow over a circular cylinder, lifting flow over a cylinder – Magnus effect – Kutta Joukowski Theorem, Real flow over smooth and rough cylinder.	
	Self-Learning Topics: *Continuity, momentum and Bernoulli's equation.*	
	Learning Outcomes : *A learner will be able to* *LO 1.1 Apply continuity, momentum, and Bernoulli's equations to analyze incompressible flow in ducts and calculate pressure coefficients. (PI 1.3.1, PI 2.4.1)* *LO 1.2 Apply the governing equation for irrotational incompressible flow, incorporating concepts like vorticity and circulation. (PI 2.3.1)* *LO 1.3 Examine the characteristics of flow over a circular cylinder, including the Magnus effect and lifting flow. (PI 2.4.1)* *LO 1.4 Differentiate between smooth and rough cylinder flows using the Kutta-Joukowski theorem and real flow models (PI 2.3.1)*	
02.	**Airfoil and Finite Wing Theory** ***Learning Objective/s:*** *1. To analyze airfoil nomenclature, characteristics, Kutta condition, and use the Kutta-Joukowski transformation and Thin Airfoil theory.* *2. To study downwash, induced drag, vortex dynamics, and Prandtl's Lifting Line Theory to calculate lift, drag, and evaluate aspect ratio effects.*	**7-9**
	Contents: **Airfoil Theory** Airfoil nomenclature, airfoil characteristics, Kutta condition, Kutta –Joukowski transformation and its applications, Thin Airfoil theory and its applications.	

	Finite Wing Theory Downwash and induced drag, Vortex Filament, Bound Vortex and trailing Vortex, Horse Shoe Vortex, Prandtl's Lifting Line Theory, lift and induced drag coefficients for elliptic lift distribution– General lift distribution – Oswald Efficiency factor - effect of aspect ratio.	
	Self-Learning Topics: *Oswald Efficiency factor - effect of aspect ratio*	
	Learning Outcomes : *A learner will be able to* *LO 2.1 Identify airfoil nomenclature, characteristics, and finite wing properties, including induced drag, downwash, and aspect ratio effects. (PI 1.4.1)* *LO 2.2 Apply Airfoil Theory and Prandtl's Lifting Line Theory to calculate lift and drag for airfoils and finite wings. (PI 2.4.1)* *LO 2.3 Interpret the roles of bound, trailing, and horse-shoe vortices in lift generation and induced drag. (PI 2.4.4)* *LO 2.4 Apply the Kutta condition and Kutta-Joukowski transformation to analyze airfoil and wing performance. (PI 2.3.1)*	
03.	**Aircraft Performance** ***Learning Objective/s:*** 1. *Examine forces, moments, drag types, drag polar, and variations in thrust, power, and fuel consumption with speed and altitude.* 2. *Evaluate level, climbing, and gliding flight, including speed, range, endurance, turning, and V-n diagrams.*	**7-9**
	Contents: Forces and moments acting on a flight vehicle, equation of motion of a rigid flight vehicle, different types of drag, drag polar of vehicles from low speed to high speeds, variation of thrust, power and SFC with velocity and altitudes for air breathing engines, power available and power required curves. Performance of airplane in level flight, maximum speed in level flight, conditions for minimum drag and power required, range and endurance, climbing and gliding flight-maximum rate of climb, turning performance - turning rate turn radius, Bank angle, V-n diagram.	
	Self-Learning Topics: *Variation of thrust, power and SFC with velocity and altitudes for air breathing engines, power available and power required curves.*	
	Learning Outcomes : *A learner will be able to* *LO 3.1 Access the forces, moments, and equations of motion for a rigid flight vehicle. (PI 2.4.1)* *LO 3.2 Determine drag types, drag polar, and variations in thrust, power, and SFC with speed and altitude for air-breathing engines. (PI 2.3.1, PI 2.4.1)* *LO 3.3 Compute performance metrics such as level flight speed, range, endurance, climb rate, and gliding efficiency. (PI 2.4.1)* *LO 3.4 Calculate turning performance, including turn rate, radius, bank angle, and interpret V-n diagrams. (PI 2.4.1)*	

04.	**Static Longitudinal Stability and Control** ***Learning Objective/s:*** *1. Evaluate static and dynamic stability, including longitudinal stability, CG effects, and power influence.* *2. Calculate stick force gradients, hinge moments, and neutral points during symmetric maneuvers.* **Contents:** Static and dynamic stability– static longitudinal stability, stick fixed stability, stability criterion, effects of fuselage and CG location, power effects, stick fixed neutral point, stick free stability, Hinge moment Coefficient, stick free neutral points, symmetric maneuvers, stick force gradients. ***Self-Learning Topics:*** *Symmetric maneuvers.* ***Learning Outcomes :*** *A learner will be able to* *LO 4.1 Identify static and dynamic stability, including longitudinal stability and stick-fixed stability criteria. (PI 2.3.1, PI 2.4.4)* *LO 4.2 Evaluate the impact of fuselage design, CG location, and power effects on flight stability. (PI 2.3.1, PI 4.1.4, PI 8.1.2, PI 9.1.2)* *LO 4.3 Determine stick-fixed and stick-free neutral points, hinge moment coefficients, and stick force gradients. (PI 2.3.1, PI 2.4.1)* *LO 4.4 Analyze stability during symmetric maneuvers, including the effect of stick force gradients on control. (PI 1.4.1, PI 2.3.1)*	**5-7**
05.	**Lateral and Directional Stability and Control** ***Learning Objective/s:*** *1. Examine dihedral effect, lateral control, and coupling between rolling and yawing moments, including adverse yaw and aileron reversal.* *2. Assess directional stability, rudder requirements, and the impact of engine failure and rudder lock.* **Contents:** Dihedral effect - Lateral control - Coupling between rolling and yawing moments - Adverse yaw effects - Aileron reversal - Static directional stability - Rudder requirements - One engine inoperative condition - Rudder lock. ***Self-Learning Topics:*** *Adverse yaw effects.* ***Learning Outcomes :*** *A learner will be able to* *LO 5.1 Investigate the dihedral effect, lateral control, and the coupling between rolling and yawing moments. (PI 2.3.1, PI 2.4.4)* *LO 5.2 Identify the causes and effects of adverse yaw and aileron reversal on flight control. (PI 2.1.2, PI 2.3.1)* *LO 5.3 Assess static directional stability and the role of rudder in maintaining stability. (PI 2.3.1, PI 2.4.1)* *LO 5.4 Analyze rudder requirements and performance during one engine inoperative*	**5-7**

	conditions and rudder lock. (PI 2.3.1, PI 4.1.4, PI 8.1.2, PI 9.1.2)	
06.	**Dynamic Stability**	**7-9**
	Learning Objective/s: *1. Identify the modes of dynamic stability, including the effect of freeing the stick on stability.* *2. Examine the dynamics of spiral, divergence, Dutch roll, auto-rotation, and spin.*	
	Contents: Introduction to dynamic longitudinal stability: - Modes of stability, effect of freeing the stick - Brief description of lateral and directional. Dynamic stability - Spiral, divergence, Dutch roll, auto rotation and spin.	
	Self-Learning Topics: *Effect of freeing the stick.*	
	Learning Outcomes : *A learner will be able to* *LO 6.1 Recognize the various modes of dynamic stability, including longitudinal, lateral, and directional stability. (PI 1.3.1, PI 2.3.1)* *LO 6.2 Analyze the impact of freeing the stick on dynamic stability in flight. (PI 2.3.1)* *LO 6.3 Investigate the dynamics of spiral, divergence, Dutch roll, auto-rotation, and spin. (PI 2.3.1, PI 2.4.4)* *LO 6.4 Evaluate the interrelationship between lateral and directional stability in dynamic flight conditions. (PI 2.3.1)*	
	Course Conclusion	**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.
2.3.1	Combine scientific principles and engineering concepts to formulate models (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
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.
4.1.4	Establish a relationship between measured data and underlying physical principles.
8.1.2	Implement the norms of practice (e.g., rules, roles, charters, agendas, etc.) of effective teamwork to accomplish a goal.
9.1.2	Produce clear, well-constructed, and well-supported written engineering documents.

Course Outcomes : Learner will be able to

1. Apply fluid mechanics equations to analyze incompressible and irrotational flows, including vorticity, circulation, and aerodynamic body effects. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4)*
2. Evaluate finite-wing effects such as lift, drag, and vortex structures to understand their impact on aircraft performance. *(LO 2.1, LO 2.2, LO 2.3, LO 2.4)*
3. Analyze aircraft performance metrics, including aerodynamic forces, flight dynamics, and engine performance with change in speed and altitude. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4)*
4. Examine aircraft stability and evaluate how design factors affect longitudinal, lateral, and directional control. *(LO 4.1, LO 4.2, LO 4.3, LO 4.4)*
5. Assess stability and control factors, such as rudder effectiveness, adverse yaw, dynamic stability modes, and lateral-directional interactions. *(LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 6.1, LO 6.2, LO 6.3, LO 6.4)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCAN602.1	2	3	--	--	--	--	--	--	--	--	--
HMCAN602.2	2	3	--	--	--	--	--	--	--	--	--
HMCAN602.3	--	3	--	--	--	--	--	--	--	--	--
HMCAN602.4	2	3	--	2	--	--	--	2	2	--	--
HMCAN602.5	2	3	--	2	--	--	--	2	2	--	--
Average	**2**	**3**	--	**2**	--	--	--	**2**	**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. J. D. Anderson, *Fundamentals of Aerodynamics*, 6th ed. New York, NY: McGraw-Hill, 2016.
2. J. D. Anderson, *Introduction to Flight*, 8th ed. New York, NY: McGraw-Hill, 2015.
3. J. D. Anderson, *Aircraft Performance & Design*, New York, NY: McGraw-Hill, 1999.
4. J. J. Bertin, *Aerodynamics for Engineers*, 6th ed. Upper Saddle River, NJ: Pearson, 2016.
5. I. H. Abbott and A. E. von Doenhoff, *Theory of Wing Sections*, New York, NY: Dover Publications, 1959.
6. R. M. Bower, *Introduction to Aircraft Performance*, New York, NY: McGraw-Hill, 1996.
7. J. R. MacGregor, *Aircraft Performance: Theory and Practice*, London, UK: Springer, 2015.

Reference Books :

1. B. R. Munson, D. F. Young, and T. H. Okiishi, *Fundamentals of Fluid Mechanics*, 7th ed. Hoboken, NJ: Wiley, 2012.
2. R. W. Fox and A. T. McDonald, *Introduction to Fluid Mechanics*, 8th ed. Hoboken, NJ: Wiley, 2011.
3. S. H. Clancy, *Aerodynamics*, 2nd ed. London, UK: Pitman Publishing, 1975.

4. G. F. G. V. R. and D. H. McElroy, *Aircraft Stability and Control*, 1st ed. New York, NY: McGraw-Hill, 1985.
5. B. Etkin and L. D. Reid, *Dynamics of Flight: Stability and Control*, 3rd ed. Hoboken, NJ: Wiley, 1996.
6. B. L. Stevens and F. L. Lewis, *Aircraft Control and Simulation*, 2nd ed. Hoboken, NJ: Wiley, 2003.
7. R. C. Nelson, *Flight Stability and Automatic Control*, 2nd ed. New York, NY: McGraw-Hill, 1998.

Other Resources :

1. NPTEL, "Introduction to Aerodynamics," Prof. B. R. Balachandran.
   Available: https://archive.nptel.ac.in/courses/101/105/101105059/

2. NPTEL, "Aircraft Stability and Control," Prof. S. K. Ghosh.
   Available: https://archive.nptel.ac.in/courses/101/104/101104062/

3. NPTEL, "Introduction to Airplane Performance," Prof. M. S. R. Anjaneyulu.
   Available: https://archive.nptel.ac.in/courses/101/104/101104061/

4. NPTEL, "Principles of Fluid Dynamics," Prof. S. K. Gupta.
   Available: https://archive.nptel.ac.in/courses/101/103/101103004/

5. NPTEL, "Aircraft Performance, Stability, and Control with Experiments in Flight," Prof. A. K. Ghosh.
   Available: https://archive.nptel.ac.in/courses/101/104/101104007/

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

Numerical Assignments (min 20 problems)	:	05 Marks
Class test	:	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.