INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

MODELLING AND OPTIMIZATION TECHNIQUES								
VI Semester: CSE(DS)								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
		L	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
ACDD19	**Open Elective**	3	0	0	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisites: Basic knowledge of linear algebra, calculus, and problem-solving using mathematical models.								

I. COURSE OVERVIEW:

This course introduces students to mathematical modeling and optimization techniques used for solving real-world decision-making problems in engineering, data science, and business. It covers linear, nonlinear, integer, and dynamic programming, along with simulation and metaheuristic methods. Emphasis is placed on formulating mathematical models, analyzing system behavior, and applying optimization tools to achieve efficient and feasible solutions. Through practical case studies and computational tools, students will gain hands-on experience in addressing complex systems and improving performance across various domains.

II. COURSE OBJECTIVES:

The students will try to learn:

I. To understand the principles of mathematical modeling and its role in representing real-life systems for optimization.
II. To explore various optimization techniques such as linear programming, nonlinear programming, and integer programming, along with their solution methods.
III. To gain insight into dynamic programming, queuing models, and simulation techniques for complex decision-making scenarios.
IV. To apply optimization and modeling techniques to solve practical problems in engineering, computer science, logistics, and data science using computational tools.

III. COURSE OUTCOMES:

CO1 **Describe** the basic concepts of mathematical modeling and optimization in decision-making processes.
CO2 **Formulate** and **solve** linear programming problems using graphical and simplex methods.
CO3 **Analyze** and **solve** integer and nonlinear programming problems using appropriate methods.
CO4 **Apply** dynamic programming techniques to multi-stage decision problems.
CO5 **Demonstrate** the use of simulation techniques and queuing models for system performance evaluation
CO6 **Develop** optimization models for real-world applications using software tools such as MATLAB, LINGO, or Python.

IV. COURSE CONTENT:

MODULE -I: MATHEMATICAL MODELLING (09)

Introduction to modelling, mathematical models, classification of mathematical models, Limitations of mathematical models, Introduction to optimization, Problem Statement, Constraints, Objective Function, Conditions for Local Minimizers, First-Order Necessary Condition (FONC), Second-Order Necessary Condition (SONC), Second-Order Sufficient Condition (SOSC).

MODULE –II: MATHEMATICAL PRELIMINARIES (10)

Vector Algebra: Vector Spaces and Matrices, Linear Transformations, Eigenvalues and Eigenvectors, Orthogonal Projections, Quadratic Forms, Matrix Norms. Calculus: Differentiability, Derivative Matrix, Level Sets and Gradients, Taylor Series, Geometry: Hyperplanes, Convex Sets, Neighborhoods, Polytopes and Polyhedral.

MODULE-III: UNCONSTRAINED LINEAR OPTIMIZATION (10)

One-dimensional search methods: Bisection, Newton, and Secant, Bracketing, Line Search in Multidimensional Optimization.

Gradient-based methods: Steepest Descent, Convergence Rate, Conjugate Gradient Methods: Conjugate direction and Conjugate Gradient (All without proofs).

MODULE-IV: CONSTRAINED LINEAR OPTIMIZATION (10)

Linear Programming: Simple Examples, Two-Dimensional Linear Programs, Convex polyhedral and Linear Programming, Standard Form Linear Programs, Basic Solutions, Properties of Basic Solutions, Geometric View of Linear Programs. Simplex Algorithm: Matrix Form of the Simplex Method, Two-Phase Simplex Method, Revised Simplex Method, Dual Linear Programs, Properties of Dual Problems (All without proofs).

MODULE-V: NONLINEAR OPTIMIZATION (09)

Problems with Equality Constraints: Problem Formulation, Tangent and Normal Spaces, Lagrange Condition, Second-Order Conditions, Minimizing Quadratics Subject to Linear Constraints. Problems with Inequality Constraints: Karush-Kuhn-Tucker Condition, Second-Order Conditions. Convex Optimization: Convex Optimization Problems, Semidefinite Programming. (All without proof)

V. TEXTBOOKS:

1. Edwin K. P. Chong & Stanislaw H. Zak, Introduction to Optimization, 4th Edition, Wiley India, 2017.
2. Clive L Dym, Principles of mathematical modelling, Elsevier Academic press, 2004, PHI Learning Private Ltd., 5th Edition, 2012.
3. Sandip Banerjee, Mathematical Modelling: Models, Analysis and Applications, CRC Press, 2nd Edition, 2022.

VI. REFERENCE BOOKS:

1. Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge University Press.
2. Dimitri P. Bertsekas, Convex Optimization, Athena Scientific, Belmont, Massachusetts, 2015.
3. Stefan Heinz, Mathematical Modelling, Springer-Verlag Berlin Heidelberg 2011.
4. Robert Hoyt, Robert Muenchen, Introduction to Biomedical Data Science, Springer-Verlag Berlin Heidelberg 2019.

VII. ELECTRONICS RESOURCES:

1. https://www.geeksforgeeks.org/optimization-algorithms-in-machine-learning/
2. https://medium.com/engineering-approach/classification-of-mathematical-models-270a05fcac4f
3. https://towardsdatascience.com
4. https://www.vedantu.com

VIII. MATERIALS ONLINE

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open-ended experiments
5. Definitions and terminology
6. Assignments
7. Model question paper – I
8. Model question paper – II
9. Lecture notes
10. PowerPoint presentation
11. E-Learning Readiness Videos (ELRV)