INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

MECHANICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**ENGINEERING OPTIMIZATION**				
Course Code	AME516				
Programme	B.Tech				
Semester	V	ME			
Course Type	PROFESSIONAL ELECTIVE -I				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	--	1
Chief Coordinator	Mrs. T Vanaja, Assistant Professor				
Course Faculty	Mrs. T Vanaja, Assistant Professor				

I. COURSE OVERVIEW:

Optimization is one of the most powerful tools in process integration. Optimization involves the selection of the "best" solution from among the set of candidate solutions. The degree of goodness of the solution is quantified using an objective function (e.g., cost) which is to be minimized or maximized. The search process is undertaken subject to the system model and restrictions which are termed constraints. Hence, the purpose of optimization is to maximize (or minimize) the value of a function (called objective function) subject to a number of restrictions (called constraints). These constraints are in the form of equality and inequality expressions.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AHS011	IV	Mathematical Transformation Techniques	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Engineering Optimization	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✘	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✔	Videos
✘	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE modules and each module carries equal weight-age in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each module. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 20 marks for Continuous Internal Examination (CIE), 05 marks for Quiz and 05 marks for Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	Theory		Total Marks
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 20 marks of 2 hours duration consisting of five descriptive type questions out of which four questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz - Online Examination

Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are to be answered by choosing the correct answer from a given set of choices (commonly four). Such a question paper shall be useful in testing of knowledge, skills, application, analysis, evaluation and understanding of the students. Marks shall be awarded considering the average of two quiz examinations for every course.

Alternative Assessment Tool (AAT)

This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning centre. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Presentation on real-world problems
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences	2	Seminar
PO 4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	1	Assignment

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Professional Skills:** To produce engineering professional capable of synthesizing and analyzing mechanical systems including allied engineering streams.	1	Seminar
PSO 2	**Software Engineering Practices:** An ability to adopt and integrate current technologies in the design and manufacturing domain to enhance the employability.	-	-
PSO 3	**Successful Career and Entrepreneurship:** To build the nation, by imparting technological inputs and managerial skills to become technocrats.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES :

The course should enable the students to:	
I	Understand the theory of optimization methods and algorithms developed for solving various types of optimization problems .
II	Develop and promote research interest in applying optimization techniques in problems of Engineering and Technology.
III	Apply the mathematical results and numerical techniques of optimization theory to concrete Engineering problems.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Define and use optimization terminology and concepts, and understand how to classify an optimization problem.	CLO 1	Understand implement basic optimization algorithms in a computational setting and apply existing optimization software packages to solve engineering problems
		CLO 2	Apply optimization techniques to determine a robust design.
		CLO 3	Apply optimization methods, exploring the solution, and interpreting results.
		CLO 4	Evaluate model engineering minima/maxima problems as optimization problems..
		CLO 5	Solve Matlab to implement optimization algorithms.
CO 2	Apply optimization methods to engineering problems, including developing a model, defining an optimization problem, applying optimization methods, exploring the solution, and interpreting results.	CLO 6	Evaluate and measure the performance of an algorithm. .
		CLO 7	Describe mathematical translation of the verbal formulation of an optimization problem.
		CLO 8	Explain design algorithms, the repetitive use of which will lead reliably to finding an approximate solution
		CLO 9	Demonstrate the ability to choose and justify optimization techniques that are appropriate for solving realistic engineering problems.

COs	Course Outcome	CLOs	Course Learning Outcome
CO 3	Understand and apply unconstrained optimization theory for continuous problems, including the necessary and sufficient optimality conditions and algorithms such as: steepest descent, Newton's method, conjugate gradient, and quasi-Newton methods.	CLO 10	Demonstrate clearly a problem, identify its parts and analyze the individual functions
		CLO 11	Explain Feasibility study for solving an optimization problem
		CLO 12	Understand the gradient and its applications.
		CLO 13	Compare , study and solve optimization problems.
CO 4	Understand and apply methods for computing derivatives such as: finite differentiating, symbolic differentiation, complex step, algorithmic differentiation, and analytic methods (direct and adjoint).	CLO 14	Understand optimization techniques using algorithms.
		CLO 15	Understand the various direct and indirect search methods
		CLO 16	Understand the Investigate, study, develop, organize and promote innovative solutions for various applications.
		CLO 17	Understand evolutionary algorithms
CO 5	Understand and apply constrained optimization theory for continuous problems, including the Karush-Kuhn-Tucker conditions and algorithms such as: generalized reduced gradient, sequential quadratic programming, and interior-point methods	CLO 18	Enable nonlinear problem through its linear approximation .
		CLO 19	Enable students to understandoptimal estimation in environmental engineering; production planning in industrial engineering; transportation problem

X. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AME516.01	CLO 1	Understand implement basic optimization algorithms in a computational setting and apply existing optimization software packages to solve engineering problems	PO 1	3
AME516.02	CLO 2	Apply optimization techniques to determine a robust design.	PO 2	2
AME516.03	CLO 3	Apply optimization methods, exploring the solution, and interpreting results.	PO 1	3
AME516.04	CLO 4	Evaluate model engineering minima/maxima problems as optimization problems..	PO 1	3
AME516.05	CLO 5	Solve Matlab to implement optimization algorithms.	PO 2	2
AME516.06	CLO 6	Evaluate and measure the performance of an algorithm. .	PO 2	2
AME516.07	CLO 7	Describe mathematical translation of the verbal formulation of an optimization problem.	PO 2	2
AME516.08	CLO 8	Explain design algorithms, the repetitive use of which will lead reliably to finding an approximate solution	PO 2	2
AME516.09	CLO 9	Demonstrate the ability to choose and justify optimization techniques that are appropriate for solving realistic engineering problems.	PO 4	1

AME516.10	CLO 10	Demonstrate clearly a problem, identify its parts and analyze the individual functions	PO 4	1
AME516.11	CLO 11	Explain Feasibility study for solving an optimization problem	PO 2	2
AME516.12	CLO 12	Understand the gradient and its applications.	PO 2	2
AME516.13	CLO 13	Compare , study and solve optimization problems.	PO 1	3
AME516.14	CLO 14	Understand optimization techniques using algorithms.	PO 1	3
AME516.15	CLO 15	Understand the various direct and indirect search methods	PO 1	3
AME516.16	CLO 16	Understand the Investigate, study, develop, organize and promote innovative solutions for various applications.	PO 1, PO 2	3
AME516.17	CLO 17	Understand evolutionary algorithms	PO 1, PO 2	3
AME516.18	CLO 18	Enable nonlinear problem through its linear approximation .	PO 1, PO 2	3
AME516.19	CLO 19	Enable students to understandoptimal estimation in environmental engineering; production planning in industrial engineering; transportation problem	PO 1, PO 2	3

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XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES

Course Outcomes (COs)	Program Outcomes (POs)			
	PO 1	PO 2	PO 4	PSO1
CO 1	3	2		1
CO 2		2	1	
CO 3	3	2	1	
CO 4	3	2		1
CO 5	3	2		1

XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 1	3												1		
CLO 2		2													
CLO 3	3												1		
CLO 4	3												1		
CLO 5		2													
CLO 6		2													

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 7		2													
CLO 8		2													
CLO 9				1											
CLO 10				1											
CLO 11		2													
CLO 12		2													
CLO 13	3														
CLO 14	3												1		
CLO 15	3														
CLO 16	3	2											1		
CLO 17	3	2											1		
CLO 18	3	2											1		
CLO 19	3	2											1		

3 = High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1, PO2, PO4,PSO1	SEE Exams	PO1, PO2, PO4,PSO1	Assignments	-	Seminars	PO1, PO2, PO4,PSO1
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	PO1, PO2, PO4,PSO1						

XIV. ASSESSMENT METHODOLOGIES - INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XV. SYLLABUS

UNIT-I	INTRODUCTION TO OPTIMIZATION
Introduction: Optimal problem formulation, design variables, constraints, objective function, variable bounds; engineering optimization problems: Classification and Some examples (just theory and discussion): truss structure, ammonia structure, transit schedule and car suspension.	

UNIT-II	UNIT-II SINGLE VARIABLE OPTIMIZATION
Single variable non-linear optimization problems: Local minimum global minimum and inflection point, necessary and sufficient conditions theorems, some problems based on this; Numerical methods: Exhaustive search methods, Fibonacci method, golden section method and comparison, interpolation methods: quadratic.	
UNIT-III	**MULTI VARIABLE UNCONSTRAINED OPTIMIZATION**
Multivariable unconstrained non-linear optimization problems: Numerical methods direct search methods: Univariate method, Pattern Search methods: Powell, Hook-Jeeve‘s, Rosen Brock‘s search and Simplex methods, multivariable unconstrained non-linear optimization problems. Gradient methods: Gradient of a function, importance, gradient direction search based methods: Steepest descent/ascent method, conjugate gradient method and variable metric method	
UNIT-IV	**MULTI VARIABLE CONSTRAINED OPTIMIZATION**
Multivariable constrained non-linear optimization problems classical optimization techniques: Constraints equations, Lagrangian method, inequalities-Kuhn-Tucker necessary and sufficient conditions, quadratic problem, Statement, Wolfe‘s and Beale‘s methods.	
UNIT-V	**GEOMETRIC AND INTEGER PROGRAMMING**
Geometric programming: posynomials, arithmetic, geometric inequality, unconstrained G.P, constrained G.P(≤ type only) integer Programming; Introduction, formulation, Gomory cutting plane algorithm, branch and bound method.	
Text Books:	
1. Kalyanmoy Deb, ―Optimization for Engineering Design‖, Prentice-Hall of India (Pvt) Ltd, New Delhi, 1 st Edition, 2005. 2. S. D. Sharma, ―Operations Research‖, Kedar Nath & Ran Nath Co., New Delhi, 1st Edition, 2013.	
Reference Books:	
1. Beveridge, Schechter, ―Optimization Theory & Practice‖, McGraw-Hill, 1st Edition, 2010.	

XVI. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Introduction to Optimal problem formulation, design variables, constraints, objective function, variable bounds	CLO 1	T2:2.3
2	Review on engineering optimization problems	CLO 1	R1:2.6
3	Discuss the examples (just theory and discussion): truss structure, ammonia structure	CLO 2	T1:2.6
4	Describe the transit schedule and car suspension	CLO 2	T2:2.7 R1:2.18
5	Describe theSingle variable non-linear optimization problems	CLO 3	T2:2.22
6	Discuss Local minimum global minimum and inflection point, necessary and sufficient conditions theorems	CLO 3	T2:2.25
7	Discuss Numerical methods: Exhaustive search methods	CLO 3	T2:2.26 R1:2.55
8	Discuss Fibonacci method, golden section method and comparison	CLO 4	T2:2.16 R1:2.61
9	Discuss the interpolation methods: quadratic.	CLO 4	T2:2.30 R1:2.58
10	Introduction to Multivariable unconstrained non-linear optimization problems: Numerical methods direct search methods: Univariate method, Pattern Search methods	CLO 5	T2:3.6 R1:4.29

11	Classifying Powell, Hook-Jeeve‘s, Rosen Brock‘s search and Simplex methods	CLO 5	T2:3.14 R1:4.31
12	Discuss Powell, Hook-Jeeve‘s, Rosen Brock‘s search and Simplex methods	CLO 6	T2:3.14 R1:4.33
13	Discuss Powell, Hook-Jeeve‘s, Rosen Brock‘s search and Simplex methods	CLO 6	R1:4.36
14	Comparison multivariable unconstrained non-linear optimization problems. Gradient methods	CLO 6	T2:3.18 R1:4.64
15	Introduction Gradient of a function, importance, gradient direction search based methods	CLO 7	T2:3.22
16	Demonstration Steepest descent/ascent method, conjugate gradient method and variable metric method	CLO 7	T2:3.28 R1:4.67
17	Demonstration Steepest descent/ascent method, conjugate gradient method and variable metric method	CLO 8	T2:4.2
18	Demonstration Steepest descent/ascent method, conjugate gradient method and variable metric method	CLO 8	T2:4.3 R1:4.71
19	Introduction to Multivariable constrained non-linear optimization problems classical optimization techniques	CLO 9	T1:4.8 R2:4.68
20-21	Demonstration of Multivariable constrained non-linear optimization problems classical optimization techniques	CLO 9	T2:4.15 R1:5.74
22	Discuss classical optimization techniques	CLO 10	T1:4.12 R2:5.75
23-24	Explanation of Constraints equations	CLO 11	T1:4.8 R1:5.72
25	Introduction to Lagrangian method	CLO 12	T1:5.8 R1:5.73
26-27	Discuss inequalities-Kuhn-Tucker necessary and sufficient conditions	CLO 12	T1:5.14 R1:6.78
28	Explain nequalities-Kuhn-Tucker necessary and sufficient conditions	CLO 13	T2:5.19 R1:6.81
29-30	Explain nequalities-Kuhn-Tucker necessary and sufficient conditions	CLO 13	T1:6.4 R2:6.8
31	Describequadratic problem, Statement, Wolfe‘s and Beale‘s methods.	CLO 14	T2:7.7 R1:7.74
32-33	Describequadratic problem, Statement, Wolfe‘s and Beale‘s methods.	CLO 14	T1:7.12 R2:8.75
34	Describequadratic problem, Statement, Wolfe‘s and Beale‘s methods.	CLO 15	T1:7.8 R1:8.72
35	Explain Geometric programming: posynomials, arithmetic, geometric inequality	CLO 15	T1:8.8 R1:8.73
36	Discuss unconstrained G.P, constrained G.P(≤ type only)	CLO 16	T1:9.14 R1:10.78
37-38	Describe integer Programming	CLO 17	T2:9.19 R1:10.814
39-40	Describe formulation, Gomory cutting plane algorithm	CLO 18	T1:10.4 R2:11.68
41-43	Discuss branch and bound method	CLO 19	T2:10.7 R1:12.74
44-45	Discuss branch and bound method.	CLO 19	T1:11.12 R2:12.75

XVII. GAPS IN THE SYLLABUS-TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S No	Description	ProposedActions	Relevance With POs	Relevance With PSOs
1	To improve standards and analyze the concepts.	Seminars	PO 1	PSO 1
2	To understand the algorithms and iterations of different optimization techniques.	Seminars / NPTEL	PO 4	PSO 1
3	Encourage students to solve real time applications and prepare towards competitive examinations.	NPTEL	PO 2	PSO 1

Prepared by:
Mrs. T Vanaja, Assistant Professor **HOD, ME**